Selected
Annotated Bibliography of TABS-MDS Numerical Modeling

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Apicella, Guy, Norris, Robert, Newton, Johanna, Ewald, Walter, Forndran, Angelika. (1994). "East River Modeling Of Water Quality For Multiple-Project Assessments," *Proceedings of the 3rd International Conference on Estuarine and Coastal Modeling III,* Oak Brook, IL. American Society of Civil Engineers, New York, 235-248.
The East River Model (ERM), which employs the RMA-2V hydrodynamic and RMA-4 water quality modeling code, was used by Lawler, Matusky & Skelly Engineers to assess water quality impacts in conjunction with a number of programs administered by the New York City Department of Environmental Protection. The two modeling applications described in this paper relate to (1) combined sewer overflow (CSO) effects on dissolved oxygen (DO) and total coliform concentrations, and (2) water pollution control plant (WPCP) effluent dilution as related to whole effluent toxicity (WET) criteria. Two dye surveys at each of the city's six WPCPs revealed that the effluent is well mixed vertically at relatively short distances from the outfall. The ERM was used to simulate the effect of the city's 239 CSO outfalls on DO and total coliform within the East River system and thereby develop a plan for CSO abatement.

Athow, R. F., Berger, R. C., Heltzel, S. B., and Trawle, M. J. (1986). "Predicting Maintenance Dredging Requirements: A Case Study, Thimble Shoal and Elizabeth River Channels, Norfolk, Virginia, USA." *XIth World Dredging Congress,* Brighton, United Kingdom, March 4-7, 1986. J. H. Volbeda, V. L. van Dam, N. Oosterbaan, ed., Central Dredging Association, Delft, The Netherlands, Section A, Part A2, Paper a, 19-33.
Describes how the TABS-2 numerical modeling system was used to study proposed channel and anchorage improvements for Norfolk Harbor. The noncohesive mode of the numerical sediment model (STUDH) was used for the Thimble Shoal Study and the cohesive mode applied to the Elizabeth River study. In both studies the finite element hydrodynamic model RMA-2V was used. Describes procedures used, noting determination of shoaling rates.

Athow, Robert F., Jr., Trawle, Michael J., and Richards, David R. (1987). "A Numerical Evaluation Of Training Structures." *Hydraulic engineering: Proceedings of the 1987 National Conference,* Williamsburg, VA, August 3-7, 1987. American Society of Civil Engineers, New York, 345-350.
A technique to evaluate estuarine training structure performance in reducing localized maintenance-dredging requirements using the US Army Corps of Engineers TABS-2 numerical modeling system is presented. An application of the two-dimensional, vertically averaged numerical model is demonstrated with emphasis on high-resolution computational grids and sediment transport. A short reach of the Columbia River estuary is simulated in the

numerical model. The modeled reach includes four spur dikes constructed to reduce shoaling in the adjacent navigation channel. Using the model, shoaling rates are predicted in the navigation channel with the dikes in place and then with the dikes removed.

Barrett, K. R. (1996). "Two-Dimensional Modeling of Flow and Transport in Treatment Wetlands: Development and Testing of a New Method for Wetland Design and Analysis." Doctoral Dissertation, Department of Civil Engineering, Northwestern University, Evanston, IL, December 1996.
No Abstract

Barrett, K. R. (1998). "Two-Dimensional Flow and Transport Modeling for Hydraulic Design and Analysis of Treatment Wetlands." Water Resources Engineering 98: Proceedings of the 1998 International Water Resources Engineering Conference (S. Abt, Editor), ASCE. Pp 520-525. 1998.
A new method (named the TABS method) for the design and analysis of treatment wetlands, via flow and transport modeling, was developed and demonstrated. The method employs flow modeling via the equations of conservation of mass and momentum, and substance transport modeling via the advection-dispersion equation, as implemented by the existing two-dimensional (depth-averaged) finite element model TABS-MD.
The TABS method extends the present standard practice in treatment wetland design of the plug-flow assumption (invalidated by tracer experiments in several wetlands) to provide a more realistic description of wetland behavior. The method enables modeling of systems with time-variable flow regimes, spatially variable vegetative density and irregular geometry and bathymetry – without requiring a priori tracer experiments.
Using easily obtainable data or design specifications (e.g., aerial photographs, basin morphology, inflow rates, weir characteristics), the method can compute a residence time distribution (RTD) and removal efficiency (RE) for a first-order removal process. The method can be applied in a "design-mode" to examine different design/operation alternatives, or in an "analysis mode" to an operating wetland.

Berger, R. C. Jr. (1990). "Channel Maintenance By Training Structures: Guidance For Numerical Model Mesh Development," Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
Training structures used to control channel currents and sedimentation, which in the past were designed by rules of thumb, are now frequently the subject of numerical model investigations. The precision and stability of numerical models representing the shallow-water equations and transport generally are strongly influenced by the nature of the computational mesh upon which the calculations take place. This condition is amplified by the presence of man-made structures in the flow. It is therefore imperative that mesh development in the vicinity of these structures be guided so that accurate and reliable shoaling predictions result.
This report uses a series of simple linear model equations applied in a finite element framework to develop guidance for the minimum mesh expansion rate, orientation, skewness, oscillation suppression, and bathymetric effects. While this effort was aimed at the TABS-2 modeling system, the findings are generally applicable to other finite element and finite difference models. Appendix A discusses the elimination of oscillations in the TABS-2 program.

Berger, R. C. (1993). "Free-Surface Flow Over Curved Surfaces", Technical Report, US Army

Engineer Waterways Experiment Station, Vicksburg, MS.

Flood flows in excess of a reservoir's capacity must be passed downstream in a manner that does not endanger the dam or surrounding hydraulic structures. This is not a trivial task, as the flow must fall a great distance to reach the riverbed. These high current velocities coupled with a free surface can easily lead to regions of low pressure in which cavitation may occur or the formation of standing waves and an uneven flow distribution. Poor flow distribution will yield circulation and high velocities at the base of the spillway (or outlet channel) known as the "stilling basin", resulting in downstream scour, potentially undermining the structure, causing bank erosion and stilling basin damage.

Numerical models of free-surface spillway flows must address high flow velocities and the nonhydrostatic pressure distribution over the curved spillway bed. Common shallow-water models invoke the hydrostatic assumption, and in the case of the St. Venant equations, also the mild-slope assumption and may not be adequate. This investigation develops the equations of a more general shallow-water formulation that includes bed curvature effects. The equations have lateral and longitudinal resolution and an assumed bed-normal velocity distribution. No restriction is placed on the velocity in the plane parallel to the bed. These equations are derived through a singular perturbation analysis in a shallowness parameter.

A finite element model is then constructed that represents a discrete version of these equations, and its usefulness is tested in comparison to water surface and pressure measurements gathered in flumes. A Petrov-Galerkin scheme is used in which the degree of modification of the original Galerkin test function is proportional to the eigenvalues, which represent the wave speed. Results with this scheme are compared to those for the standard steep-slope shallow-water equations are a significant improvement over these more conventional equations near the spillway crest and thus in the prediction of the spillway capacity. The St. Venant equations compare more poorly along the spillway face, but this is shown to be a result of the mild-slope assumption, not curvature. Laterally, the new generalized shallow-water equations provide only slight improvement over conventional equations in that the water surface is generally controlled by short-wave phenomena, and these models are all essentially long-wave models. They do provide some qualitative guidance on spillway performance.

Berger, R. C. (1990). "Mass Conservation In The RMA2V Code." *Hydraulic Engineering: Proceedings of the 1990 National Conference,* San Diego, CA, July 30-31, 1990. American Society of Civil Engineers, Boston Society of Civil Engineers Section, Boston, MA, 2, 873-878.

This paper discusses the RMA2V hydrodynamic code with a particular interest in mass conservation problems. These originate from at least two sources. One of which is the slip flow boundary specification in which the boundary slopes are not continuous and the second is due to the formulation itself. The severity of these problems is estimated and recommendations made to improve the model behavior.

Berger, R. C., McAdory, R. T., Martin, W. D., and Schmidt, J. H. (1995). "A Houston-Galveston Navigation Channels, Texas Project; Three-Dimensional Hydrodynamic Model Verification," Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

This report describes the verification results of the three-dimensional (3-D) hydrodynamic model used to evaluate tides, current velocities, and salinities in Galveston Bay, Texas. This is the third in a series of reports concerning the Houston-Galveston Navigation Channels. The goal of these reports is to determine the effect of the proposed channel deepening and

widening upon tides, currents, salinities, and navigation. Report 1 describes the field data collection and results, Report 2 presents the two-dimensional numerical modeling of hydrodynamics for a navigation study, Report 3 presents the verification description for the 3-D model, and Report 4 details the results of tests of the 3-D model.
This report first describes the 3-D model program, RMA10-WES, which is a finite element code using mixed quadratic and linear Lagrange polynomials. The remainder of the report reveals the demonstration of the model applicability through the verification procedure. This procedure of adjustment and verification was first a comparison to a short series of data with a series of adjustments in bed roughness. Then the model was run with no adjustment over a period of roughly 6 months in comparison to field data from 19 July 1990 to 15 January 1991. This period includes the time following a major flood in the Galveston Bay system for which the model reproduces the timing and magnitude of the salinity rebound very well. Comparisons of model performance are drawn qualitatively between the model and description of the Bay in the literature, and also quantitatively with the field data recorded for this study.

Berger, R. C., Jr., Heltzel, Samuel B., Athow, Robert F., Jr., Richards, David R., Trawle, Michael J. (1985), "A Norfolk Harbor And Channels Deepening Study; Report 2, Sedimentation Investigation; Chesapeake Bay Hydraulic Model Investigation," Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
This report presents the sedimentation findings from combined physical and numerical model tests (hybrid modeling) of deepening the approach channels to Norfolk and Newport News, VA. Because of the varying nature of shoaled material along the project navigation channel, the tests included two separate numerical sediment transport models, which were referred to as the Thimble Shoal model and the Elizabeth River model. The sediment along the Thimble Shoal portion of the navigation channel consists predominantly of noncohesive material while the sediment along the Elizabeth River portion of the navigation project consists primarily of clays and silts. Sedimentation in a third portion of the overall project, referred to as the Atlantic Ocean Channel, was evaluated analytically without using a numerical sediment transport model.

Berger, R. C., McAdory, Robert T., Schmidt, Joseph H., Martin, William D., and Hauck, Larry H. (1995). "A Houston-Galveston Navigation Channels, Texas Project; Three-Dimensional Numerical Modeling Of Hydrodynamics And Salinity," Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
This report describes the testing program conducted to evaluate the impact of enlargement of the Houston-Galveston Navigation Channel on the salinity and hydrodynamic fields of tidally influenced Galveston Bay. The present channel nominal dimensions are 40 ft deep at mean low water (mlw) and 400 ft wide. The proposed enlargements tested are for a channel 45 ft deep at mlw and 530 ft wide (Phase I) and 50 ft deep and 600 ft wide (Phase II). Current plans do not include the Phase II enlargement. Salinity fields for these channel configurations and the existing channel dimensions are compared. In a separate study the results from these simulations were used to drive an ecosystem model to predict oyster production.
Testing conditions included tidal conditions and winds for the year 1984. The freshwater inflows (developed outside this study) were tested for low-, medium-, and high-flow years. Additionally, since water demand in the future is expected to modify freshwater distribution and quantities, future distributions for the test year 1999 (Wallisville Dam in place), 2024, and the code used (RMA10-WES) is a Galerkin-based finite element solution to simulate three-

dimensional (3-D) unsteady open-channel flow. The code represents 3-D hydrodynamics using conservation of fluid mass, horizontal momentum, and salinity/temperature transport equations subject to the hydrostatic assumption.
The deepened channels showed increased salinity stratification. The stratification increased with channel project depths and with freshwater inflow in the Buffalo Bayou/San Jacinto River Basin.

Berger, R. C., and Stockstill, R. L. (1995). "Finite-Element Model for High-Velocity Channels," *Journal of Hydraulic Engineering,* American Society of Civil Engineers, ISSN 0733-9429/95/0010-0710-0716.
Numerical modelers of high-velocity channels are faced with supercritical transitions and the difficulty in capturing discontinuities in the flow field, known as hydraulic jumps. The implied smoothness of a numerical scheme can produce fictitious oscillations near these jump locations and can lead to instability. It is also important that the discrete numerical operations preserve the Rankine-Hugoniot conditions and accurately model jump speed and location. The geometric complexity of high-velocity channels with bridge piers and service ramps are easily represented using an unstructured model. A two-dimensional finite-element model that utilizes a characteristic based Petrov-Galerkin method and a shock-detection mechanism, which relies on elemental energy variation results in a robust system to model high-velocity channels. Comparisons are made between analytic shock-speed results, published laboratory data of a lateral contraction, and with a more general physical model.

Berger, R. C., and Stockstill, R. L. (1994). "Considerations in 2-D Modeling of Hydraulically Steep Flow," *Proceedings of the 1994 National Conference on Hydraulic Engineering,* American Society of Civil Engineering.
Simplifications in the equations used to describe shallow water flow lead to some difficulties in modeling supercritical flow. The hydrostatic assumption produces two significant differences from the actual flow, in that the model's wave celerity is too large and that the energy associated with vertical motion is dissipated instantly. These differences lead to standing waves that protrude into the flow at a greater angle than those produced by the actual flow and a tendency to dissipate succeeding waves too quickly.

Berger, R.C. (1993). "A Finite Element Scheme for Shock Capturing; Technical Report", US Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.
The representation of hydraulic jumps or shocks in compressible fluids is a difficult task for numerical models. These models require more smoothness than the analytic solution contains. For this reason these models are plagued with oscillations. The most widespread method is to smear the solution in the vicinity of the shock, giving up 0(1) errors, but restricting the error to the neighborhood of the jump or shock. This technique is called shock capturing.
In this report a method to capture hydraulic jumps formed by the shallow-water equations in a finite element model (HIVEL2D) is demonstrated. The model itself is two-dimensional. The method it relies upon is a Petrov-Galerkin approach in which the degree of upstream bias in the test function is based upon the characteristics of the convection matrix. Furthermore, in order to restrict the shock capturing to the vicinity of the jump, a method of jump detection is implemented which depends on the variation of mechanical energy within an element.
The veracity of the model is tested by comparison of the predicted jump speed and magnitude with analytic and flume results. A comparison is also made to a flume case of steady-state

supercritical lateral transition.

Berger, R. C., and Stockstill, R. L. (1993). "A 2-D Numerical Model for High Velocity Channels," *Proceedings of the 1993 National Conference on Hydraulic Engineering,* American Society of Civil Engineers.
The hydraulic performance of a high velocity channel depends on maintaining a supercritical flow regime over specified portions of its length. Predicting the potential location of shocks such as oblique standing waves and hydraulic jumps and determining the super elevation of the water surface in channel bends is necessary to design the required wall heights. Work is being conducted to develop a numerical flow model that can estimate the location and velocity channels. The high velocity channel model, HIVEL2D, is a depth averaged two-dimensional (2-D) flow model designed specifically for flow fields containing supercritical and sub critical regimes as well as the transitions between the regimes. This paper summarizes the numerical scheme and presents some of the initial test results of HIVEL2D, currently under development at the U.S. Army Engineer Waterways Experiment Station.

Berger, R. C. (1994.) "A Finite Element Model Application to a Study of Circulation and Salinity Intrusion in Galveston Bay, Texas," Chapter 10, in *Finite Elements in Environmental Problems,* ed. G. F. Carey, John Wiley & Sons, West Sussex, England, 177-194, 17 pages
No Abstract

Bernard, R.S., and Schneider, M.L., (1992.) "Depth-Averaged Numerical Modeling for Curved Channels". Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS
No Abstract

Bierman, Victor J. (2000) "Further Site Characterization and Analysis Volume 2D-Revised Baseline Modeling Report, Hudson River PCB's Reassessment RI/FS," U.S. Environmental Protection Agency, Region 2 and U.S. Army Corps of Engineers, Kansas City District, Volume 2D-Book 1 of 4, Fate and Transport Models, TAMS Consultants, Inc., Limno-Tech, Inc., Tetra Tech, Inc.
The six-mile long Thompson Island Pool is a special area of focus in the Reassessment because it contains a disproportionate amount of the PCB mass (nearly half) in the 40-mile long portion of Upper Hudson River. Additionally, the highest PCB concentrations occur in the Pool. These factors have made the Pool a focus area for possible remediation. The Pool is also the most extensively sampled reach of the Upper Hudson. As a result of the special focus on the Pool and the greater data availability, a fine scale, two-dimensional depth-averaged hydrodynamic model (U.S. Army Engineers RMA 2V) was applied for the Pool to provide input to the PCB fate and transport model (Chapter 5) and the Depth of Scour Model (Chapter 4). The Depth of Scour Model uses fine scale velocity information from the hydrodynamic model to compute scour of sediments, especially under high flow conditions.

Byars, M., Zevenbergen, L., and Lagasse, P. (2000). "2-Dimensional Modeling of a Tidal Inlet for Bridge Scour Countermeasure Design," Ayres Associates, Fort Collins, CO.
A hydrodynamic model study was performed for the Florida Department of Transportation (FDOT), District 7, to design countermeasures for the bridge, which spans Johns Pass Inlet in Pinellas County, Florida. Johns Pass is a tidal inlet that has lowered by more than 25 feet

since construction of the bridge in 1971. Crutch bents were installed to retrofit the bridge in the 1980's as channel lowering was threatening the stability of the structure. The bridge was rated scour critical in 1995 in accordance with the district-wide scour evaluation program and preliminary countermeasures for the bridge were recommended in 1997.
A 2-dimensional model study was performed as an integral part of the final design of countermeasures. The numerical analysis was performed using RMA-2V, a finite element, 2-dimensional, depth averaged hydrodynamic model maintained by the U. S. Army Corps of Engineers Research and Development Center, Waterways Experiment Station. Additional features were coded into the model to simulate the effects of pier drag, roadway overtopping and friction losses as a function of relative roughness height. The model was used to predict the ultimate equilibrium depth of the inlet and to design countermeasures for the bridge. The response of the inlet to countermeasure alternatives was determined in the analysis.
The 2-dimensional model study provided reliable data on which the bridge countermeasures were designed. The study utilized state-of-the-art technology to assess the long-term problem and provided a dependable solution. The added features to the RMA-2V model will widen its applicability to bridge related problems in the new millennium.

Byars, M., Hunt, J., Zevenbergen, L., and Lagasse, P. (2000). "Georgia Department of Transportation Hydraulic Modeling Studies and Bridge Scour Analysis," Ayres Associates, Fort Collins, CO.
This project for GADOT included hydraulic analysis of more than fifty bridge waterways in Camden, Liberty, Macintosh, Glynn and Bryan Counties in Georgia. The analyses were performed using UNET (1-dimensional hydrodynamic model) and RMA2 (2-dimensional hydrodynamic model), HEC-RAS, HY-8 and tidal prism estimates. Results were used for scour elevations for the design of widening I-95 bridges. Some of the major tidal river systems included the Satilla River, South Newport River, North Newport River, Brunswick River, and Jerico River.

Chandy, J., Morris, F. W., and Miller, S. J. (1999). "Evaluation of the Effect of Canal Plugs on the Modification of St. Johns Marsh Conservation Area Hydraulics in the Upper St. Johns River Basin." Division of Engineering, Division of Environmental Sciences, Water Resources Department, St. johns River Water Management District, Palatka, Florida.
The objective of this numerical modeling project is to evaluate the impacts of canal plugs on wetland hydrology. In 1987, a series of eight earthen canal plugs were placed in a main drainage canal in the Upper St. Johns River Basin to attempt to re-establish wetland sheet flow and to prevent marsh over drainage. While canal plugs retarded canal flow and re-hydrated the marsh, they also prevented the areas of the marsh contiguously upstream of the plugs from experiencing shorter intensity drying events that are essential to maintaining emergent marsh vegetation. As a result of prolonged inundation periods, nearly 1000 acres of emergent marsh (immediately) upstream of the plugs were converted to shallow open water flats. This resulted in undesirable vegetation shifts toward more flood tolerant species. In 1998, we developed a two-dimensional depth averaged finite element (U.S. Army Corps of Engineers RMA2) model to predict surface water elevations over the marsh under a variety of plug configurations. Our objective was to design an optimal plug configuration that would re-create more natural flow conditions in the marsh while minimizing the number of plugs. The model was calibrated from stage data measured during Tropical Storm Gordon and during normal dry season flows. The model was validated using stage data collected during the 1996 and 1997 wet season. The model indicated that appropriate marsh hydrology could be created using three canal

plugs instead of eight.

Chandy, J., and Morris, F. (2000). "Application of a 2D Finite Element Model to Tolomato Guana Rivers" under preparation. St. Johns River Water Management District, Palatka, FL. No Abstract

Cheramie, Kirk. (1995). "A Hydrologic Modeling Of Fresh Water Resources. *Coastal Zone: Proceedings of the Symposium on Coastal and Ocean Management,"* Tampa, FL. American Society of Civil Engineers, New York, 294-295.
This paper specifically identifies the TABS-MD model designed by the U.S. Army Corps of Engineers, Waterways Experiment Station as an effective management tool for efficiently supplying raw fresh water resources to coastal communities. Through the use of the TABS-MD computer model, the Bayou Lafourche Fresh Water District, a state political sub-district, is able to adequately supply fresh water to eight percent of the population of Louisiana. The model incorporates boundary conditions such as tidal range, stage, velocity and constituent concentrations within Bayou Lafourche, a 110-mile fresh water channel between the Mississippi River and the Gulf of Mexico. By setting boundary conditions and executing the model, management can decide upon the quantity of fresh water that must be pumped into Bayou Lafourche at its headwaters in order to regulate salinity concentrations at fresh water intakes at its southern most locations. By accurately determining the amount of fresh water required to offset saltwater intrusion, the expenditure of public tax dollars on electricity and fuel for fresh water pumps are better estimated, yielding savings to the public while at the same time insuring an adequate fresh water supply.

Coleman, Wesley E., Jr. (1992). "A Chesapeake Bay Field Modeling And Monitoring Projects. *Coastal Engineering Practice '92,"* Long Beach, CA, March 9-11, 1992. American Society of Civil Engineering, New York, 221-233.
'Traditional' erosion control measures often do not meet the Corps of Engineers' requirement for economic justification. The costs of these measures are much greater than the benefits provided. The costs are also prohibitive to property owners seeking shoreline protection. The Chesapeake Bay Shoreline Erosion Study has provided information for designing offshore breakwaters more cost-effectively to encourage implementation of these measures in the interest of Bay-wide improvement. Offshore breakwaters were installed at two locations in the Bay, and their performance was monitored.

Comes, Bradley M., Copeland, Ronald R., and Thomas, William A. (1989). "A Red River Waterway, John H. Overton Lock and Dam; Report 5, Sedimentation In Lock Approaches; TABS-2 Numerical Model Investigation," Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
A two-dimensional numerical model, TABS-2, was used to predict fine sediment deposition in the lock approach channels upstream and downstream from the John H. Overton Lock and Dam on the Red River Waterway, Louisiana. The numerical model was used to evaluate the effects of various design changes on fine sediment deposition. These included changing the length and height of divider dikes, the number of openings on the ported guard wall, the invert elevation in the lock approach channel, and the location of spur dikes.

Copeland, Ronald R., and Thomas, William A. (1988). "A Red River Waterway Sedimentation Study Downstream From Lock and Dam No. 1; Numerical Model Investigation," Technical

Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
The effect of recently constructed and proposed channel improvements on sedimentation in the Red River downstream from Lock and Dam No. 1 were investigated. A one-dimensional numerical model (HEC-6) was used to evaluate the effect of contraction works on dredging requirements in the navigation channel. A two-dimensional numerical model (TABS-2) was used to evaluate proposals to reduce deposition in the downstream lock approach channel at Lock and Dam No. 1. Recommendations were made to reduce sediment problems in the study reach.

Copeland, Ronald R., Comes, Bradley M., and Thomas, William A. (1991). "A Red River Waterway, Lock and Dam No. 3; Report 5, Sedimentation In Lock Approaches; TABS-2 Numerical Model Investigation," Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
A two-dimensional numerical model, TABS-2, was used to predict fine sediment deposition in the lock approach channels upstream and downstream from Lock and Dam No. 3 on the Red River Waterway, Louisiana. The numerical model was used to evaluate the effects of various design changes on fine sediment deposition. These included the cross-section shape in the upstream lock approach channel, the distance between the lock wall and the first spillway gate, the number of openings in the ported guard wall, and location of a berm in the upstream channel.

Copeland, Ronald R., Heath, Ronald E., and Thomas, William A. (1990). "A Red River Waterway, Lock and Dam No. 4; Report 5, Sedimentation In Lock Approaches; TABS-2 Numerical Model Investigation," Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
A two-dimensional numerical model, TABS-2, was used to predict fine sediment deposition in the lock approach channels upstream and downstream from proposed Lock and Dam No. 4 on the Red River Waterway, Louisiana. The numerical model was used to evaluate alternative designs. Fine sediment deposition with the proposed design at Lock and Dam No. 4 was compared to fine sediment deposition at existing locks and dams downstream.

Copeland, Ronald R., Combs, Phil, and Little, Charles D. (1989). "Application Of 2-D Model To Reduce Sedimentation Problems." *Sediment Transport Modeling: Proceedings of the International Symposium,* New Orleans, LA, August 14-18, 1989. American Society of Civil Engineers, New York, 124-129.
The Corps of Engineers opened Lock and Dam No. 1 on the Red River Waterway in 1984. During the first runoff season, excessive quantities of fine sediment deposited in both the upstream and downstream lock approach channels. Two-dimensional numerical model studies using the TABS-2 computer programs were conducted to determine remedial measures to significantly reduce hydraulic dredging, especially in the vicinity of the lock miter gates. This paper addresses the studies and evaluates the effectiveness of the construction measures.

Deering, Michael K. (1990). "A Practical Applications of 2-D Hydrodynamic Modeling. *Hydraulic Engineering: Proceedings of the 1990 National Conference,* San Diego, CA," July 30-31, 1990. American Society of Civil Engineers, Boston Society of Civil Engineers Section, Boston, MA, 2, 755-760.
Two-dimensional hydrodynamic modeling capability has greatly impacted the hydraulics community and significantly altered the approaches to design and analysis of open channel systems. Two-dimensional modeling has the potential for eliminating over simplified

assumptions associated with one-dimensional modeling. In some cases it may negate the need for physical model studies. Five case studies that employed two-dimensional hydrodynamic methods are presented.

Demissie, Misganaw, Soong, David, and Bhowmik, Nani G. (1988). "A Hydraulic Study For The Construction Of Artificial Islands In Peoria Lake, Illinois. *Hydraulic engineering: Proceedings of the 1988 National Conference on Hydraulic Engineering,* Colorado Springs, CO, August 8-12, 1988." American Society of Civil Engineers, New York, 340-345.
Long-term sediment accumulation in the lake reduced the average depth of the lake from 8 feet in 1903 to 2.6 feet in 1985, which resulted in the deterioration of aquatic habitats and recreational areas in the lake. A detailed hydraulic analysis was needed to evaluate the feasibility creating islands in Peoria Lake. The major hydraulic considerations include determining the optimum locations for the islands in terms of minimizing the sedimentation rates around the islands. A hydraulic study was conducted to investigate the best locations for constructing islands in the lake. The study made use of the one-dimensional HEC-6 sediment transport model and the two-dimensional TABS-2 hydrodynamic model. Field data were also collected to establish existing lake-bottom profiles and velocity distributions at selected locations.

Donnell, Barbara Park, and Letter, Joseph V. Jr. (1992). "The Atchafalaya River Delta, Report 12, Two-Dimensional Modeling Of Alternative Plans And Impacts On The Atchafalaya Bay And Terrebonne Marshes," Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
The Wax Lake Outlet and Atchafalaya River deltas in Louisiana have grown dramatically, and concern over the impact of this growth has led the US Army Corps of Engineers to conduct an investigation to predict how the deltas will evolve over the next 50 years. An additional task was to determine the impacts of that growth on navigation, flood control, salinity, and sedimentation in the bay area. The technical approach for this investigation builds upon the TABS-2 finite element numerical modeling system and is fully described in Report 11 of this series.

Comparisons of the existing condition results with various alternatives are presented. In summary, the extension of the Avoca Island Levee to Deer Island (Reach 2) resulted in an approximate 8 percent increase in the predicted size of the 50-year delta evolution regardless of other constraints tested. For all alternatives tested, the size of the 50-year sub aerial delta fell within the bounds of 56 to 144 square miles. The most extreme delta evolution simulation tested was the condition without the Wax Lake Outlet flow control project, no navigation channel dredging, and no levee extension. For all delta evolution simulations tested, the water surface elevations within area east of the levee increased from 3.4 to 6.0 ft by year 2030. In each case tested, the Avoca Island Levee Extension to Reach 2 decreased the backwater effect of the 50-year delta by approximately 2 ft.

Donnell, Barbara Park, Letter, Joseph V. Jr., and Teeter, Allen M. (1991). "The Atchafalaya River Delta, Report 11, Two-Dimensional Modeling," Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
The Wax Lake Outlet and Atchafalaya River deltas in Louisiana have grown dramatically, and concern over the impact of this growth has led the US Army Corps of Engineers to conduct an investigation to predict how the deltas will evolve over the next 50 years. The goal was to

design a series of modeling tools capable of predicting delta evolution and the impacts of that growth on navigation, flood control, salinity, and sedimentation. The technical approach for this investigation was built upon the TABS-2 finite element modeling system. The fully two-dimensional models for hydrodynamics, salinity, and sediment transport were first verified to extensive prototype data, the employed to predict delta evolution for existing conditions at years 1980, 1995, 2010, and 2030 within the project area. Subsidence estimates for the system were made by regression of historical water-surface elevation gaging stations.

Donnell, Barbara Park, and Letter, Joseph V. Jr. (1992). "The Atchafalaya River Delta, Report 13, Summary Report Of Delta Growth Predictions," Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
Coastal Louisiana is experiencing dramatic and alarming land loss. The exception to this general trend is the Atchafalaya River delta, which has been experiencing dramatic deltaic growth during the past 20 years. This deltaic activity can be viewed as both a resource for development of coastal wetlands and as a threat for potentially aggravating flooding in communities upstream of the delta. In response to these concerns, the Corps of Engineers is conducting a thorough investigation to predict how the delta will evolve over the next 50 years, the impacts of the growth and the effectiveness of structures for controlling detrimental results. The investigation approach used several analytical and numerical techniques applied separately to arrive at independent predictions of delta growth. The approach was arranged to provide results from increasingly sophisticated techniques over the period 1980-1989. Each of the techniques are summarized and comparisons are made. The techniques included: analytical model, regression/extrapolation analysis of past behavior, generic analysis of similar deltas= growth patterns, a quasi-two-dimensional numerical model, and TABS two-dimensional numerical model. The results from these techniques indicated a wide possible range of 32 to 149 square miles of sub aerial delta for year 2030. A regression analysis of all of these results predicted the sub aerial delta area to peak at year 2035 with 89 square miles.

Droz, P., Essyad, K., Cellino, M., and Lepicard, S. (2000). "Efficiency Assessment Of A Flood Protection Dyke In The Exclusion Zone Of Chernobyl." In "New Trends In Water And Environmental Engineering For Safety and Life: Eco-compatible Solution For Aquatic Environments", Balkema ed.
No Abstract

Elliot, R. C. (2000). Ross Island Turbidity Study, Northwest Hydraulic Consultants, Inc., Tukwila, WA.
SMS was used to develop a numerical model of the Ross Island area, to assess hydrodynamic and turbidity dispersion conditions for a range of flow and tidal and scenarios on the Willamette River near Portland, Oregon. The RMA-2 2D finite element model was used to compute hydrodynamic conditions in the project area, which includes the mainstream, a side-channel, and a lagoon. The RMA-4 constituent transport model was then used to assess dispersion characteristics of the study area.

Elliot, R. C. (2000). Rogue River Estuary, Northwest Hydraulic Consultants, Inc., Tukwila, WA.
SMS was used to develop a 2D RMA-2 model of the lower five miles of the Rogue River and its estuary into the Pacific Ocean, located along the Southern Oregon coast. Alternative schemes were investigated for alleviating shoaling problems along the dredged access channel and entrance to the jetty-defined Rogue River boat basin. Boundary conditions included

varying discharge inflows with an open tidal boundary.

Evans, Robert A. (1992). "Lockwood's Folly Numerical Circulation Study," Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
The region around Lockwoods Folly River and Inlet, North Carolina, has experienced increased development in the past 50 years. In addition, the inlet has been changed by the addition of the Atlantic Intracoastal Waterway (AIWW). There have been concerns that the circulation is not sufficient to maintain good water quality. These concerns led the US Army Corps of Engineers to conduct an investigation to determine the effect of the AIWW on overall circulation patterns. The technical approach for this investigation was built upon the TABS-MD finite element modeling system. The two-dimensional model for hydrodynamics was first validated to limited prototype data, then used in conjunction with the transport model to predict the changes in tracer levels between the base condition and three plan conditions.

Fagerburg, T. L., Coleman, Clara J., Parman, Joseph w., Fisackerly, George M. (1992). "Cumberland Sound Monitoring; Report 3, 1990 Data Collection Report," Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
Water level, conductivity, temperature, and salinity were measured in the Cumberland Sound study area during January 1990 through December 1990. The data were collected as part of a long-term study to assess, through comparisons with earlier data collection programs, if changes to the estuarine processes of the study area have occurred. This report describes the equipment and procedures used in the data collection effort and presents tables and plots of representative data.

Fagerburg, T. L., Knowles, S.C., Fisackerly, George M., Parman, Josepth W., and Benson, Howard A. (1992). "Hydrodynamic Data Collection in Cumberland Sound, Georgia," Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
A 5-year estuarine monitoring program was established in Cumberland Sound to obtain seasonal, long-term, continuous monitoring of water levels and conductivity and temperature measurements. Midway through the program, an intensive hydrodynamic data collection effort was scheduled to obtain post channel modification data of current speeds and directions, salinity and suspended sediment concentrations, water levels, and wind speed and direction. These data are to be compared with data obtained prior to the channel modifications. All of the field data collected in Cumberland Sound during May 1990 are presented. The report also describes the field investigation methods used to collect the data, summarizes laboratory methods used to analyze samples, shows results of the data reduction efforts, and presents compiled data sets.

Fagerburg, T. L. (1990). "A Mississippi River-Gulf Outlet, Louisiana, Field Data Report," Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
Water levels, current speeds and directions, salinities, and suspended sediment concentrations were measured in the Mississippi River-Gulf Outlet Canal, New Orleans, LA, in October and November 1988. The prototype data were collected as part of a study to incorporate these data in a numerical model for determination of shoaling rates. This report describes the equipment and procedures used in the data acquisition and presents tables, plots, and summaries of all the data collected.
Attempts to correlate ground truth suspended sediment data with the satellite data were unsuccessful due to cloud cover during the periods data were obtained.

Fisackerly, G.M., Fagerburg, T.L., and Knowles, S.C. (1991). "Estuarine Dynamics at Cumberland Sound, Georgia, USA".

Cumberland Sound is a complex estuarine system located along the southeast coast of Georgia, USA. The 240 mile estuary is fed by two rivers which are minor sources of suspended sediment. St. Mary's Entrance, which connects the estuary with the Atlantic Ocean, has a spring tidal prism between 6x10 and 10x10 cubic feet. The navigation channel serving the Kings Bay Naval Submarine on Cumberland Sound has been widened and deepened in recent years to accommodate larger submarines. A 5-year study (1988-1992) is being conducted to assess the effects of the channel improvements on the estuarine and coastal processes in the area of Cumberland and Amelia Islands, and Cumberland Sound. In May 1990, an intensive hydrodynamic survey of the estuary was conducted as part of the 5-year study. Hourly, variable depth current speed and direction, salinity, and suspended sediment data were collected from seven multi-station ranges in Cumberland Sound. Suspended sediment loads were low during the survey, averaging between 15 and 20 mg/1.

Fischenich, J. Craig. (1990). Accumulative Impacts Analysis On A Midwest Fluvial System. *Hydraulic Engineering: Proceedings of the 1990 National Conference,* San Diego, CA, July 30-31, 1990. American Society of Civil Engineers, Boston Society of Civil Engineers Section, Boston, MA, 2, 802-807.

The US Army Corps of Engineers recently completed an analysis of the cumulative impacts of erosion control structures on the Platte River in Nebraska. This was done in response to concerns about the effects of bank stabilization activities upon threatened and endangered species that use the Platte River. Physical changes to the river generated by existing and proposed bank stabilization activities were evaluated to determine the environmental significance of various bank stabilization structures. HEC-6, a one-dimensional sediment transport model was used to quantify cumulative impacts from bank stabilization activities for the entire river. TABS-2, a two-dimensional sediment transport model was used to quantify local impacts from a variety of structures.

Fitzgerald, P., (1998). "Modified Water Deliveries to Everglades National Park, Two-Dimensional Hydraulic Model Development," U.S. Army Engineer District, Jacksonville, FL.

No Abstract

Fitzerald, P., (1997). "Kissimmee River Restoration, Two-Dimensional Hydraulic Modeling," U.S. Army Engineer District, Jacksonville, FL.

No Abstract

Ford, R. Glenn, Sobey, Rodney J., Shrestha, Parmeshwar L., Saviz, Camilla M., Orlob, Gerald T., King, Ian P. (1993). "A San Francisco Bay and Delta Oil Spill Fate Studies. Part II: Oil Spill Simulation." *Proceedings, National Conference on Hydraulic Engineering,* San Francisco, CA. American Society of Civil Engineers, New York, 641-646.

Because of the presence of oil refineries and significant tanker and barge traffic in the bay and delta region, the possibility of a moderate or major spill in the area must be considered. We have constructed a general model that calculates a Lagrangian element solution for an oil spill in this region. Surface currents are simulated using output from the U.C. David RMA-2V model. We combine the surface current fields with real time sequences of wind speed and direction collected at eight sites in the bay and delta areas during 1990 and 1991 interpolated

to form a smooth spatially varying wind field. A random diffusive component is added to simulate spreading. The magnitude of the diffusive component and the number of Lagrangian elements are adjusted to simulate spills of varying sizes. Characterization of intertidal substrates in this area is based on 1:24,000 scale digital maps and the National Wetlands Inventory. Oil particles are not permitted to cross-exposed mud or marsh, or they are assumed to strand if they are already over these substrates as the tide ebbs.

Freeman, Gary, and Weissinger, Lisa. (1991). "TABS-2 Application To Kawainui Marsh Flood Control." *Proceedings of the 1991 National Conference on Hydraulic Engineering,* Nashville, TN, July 29-August 2, 1991. American Society of Civil Engineers, New York, 292-297.
The TABS-2 mathematical modeling system was used to evaluate the effectiveness of alternatives designed to eliminate flooding problems in the Kawainui Marsh located in Kailua on the east side of the island of Oahu, Hawaii. The study required unique applications of the TABS-2 modeling system. The verification required altering the numerical code to model free flow over the existing Federally constructed flood control levee which overtopped during the 31 December 1987 storm event and caused extensive damage to the community of Coconut Grove. One of the alternative plans consisted of placing a series of 15 culverts in the existing levee in order to drain the marsh floodwaters into an extension of the Oneawa channel and release them into the Pacific Ocean. This alternative required the addition of culvert modeling capability to the TABS-2 numerical code. These two applications were further exacerbated by the requirement to use dynamic flow simulations in order to accurately model the effects of various hydrographs. The modeling techniques employed and various model results are presented.

Granat, Mitchell A., and Brogdon, Noble J. (1990). "A Cumberland Sound and Kings Bay Pre-Trident and Basic Trident Channel Hydrodynamic and Sediment Transport Hybrid Modeling; Volume I: Main Text and Appendixes A, C, and D," Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
A previously verified hybrid modeling system (coupled physical and numerical models) of the Kings Bay/Cumberland Sound estuarine system was used to investigate hydrodynamic and sedimentation variations associated with Trident channel expansion. The models generally demonstrated small velocity differences between the pre-Trident base channel condition and the enlarged Trident channel condition tested. Reduced velocity magnitudes in the deepened upper Kings Bay turning basin demonstrated the largest base-to-plan velocity differences. Subtle circulation differences were identified. The deepened and widened Trident plan channel increased flood and ebb volume transport efficiency of the submarine channel through St. Mary's Inlet into Cumberland Sound and Kings Bay. Increased discharge through the past Kings Bay changed the phasing relationships north of Kings Bay.

Granat, Mitchell A., Brogdon, Noble J., Cartwright, John T., and McAnally, William H., Jr. (1989). "Verification Of The Hydrodynamic And Sediment Transport Hybrid Modeling System For Cumberland Sound and Kings Bay Navigation Channel, Georgia," Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
A hybrid modeling system (coupled physical and numerical models) was developed to investigate the hydrodynamic and sedimentation processes of Cumberland Sound and the interior Kings Bay navigation channel. The hybrid modeling procedures and the physical and numerical model verifications are described in detail.
The Kings Bay physical model was an accurately scaled fixed-bed concrete model of the Cumberland Sound/Kings Bay estuarine system. The physical model provided the means of

assessing three-dimensional hydrodynamic characteristics of Cumberland Sound and Kings Bay. It also provided the boundary forcing conditions for the numerical model and an expanded database for comparison. Verification of the physical model to reproduce pre-Trident channel field measurements collected during November 1982 and transitional channel conditions measured during January 1985 was demonstrated.

The other component of the modeling system was the US Army Corps of Engineers Generalized Computer Program System: Open-Channel Flow and Sedimentation, TABS-2. TABS-2 is a complete depth-averaged finite element numerical modeling system. The numerical hydrodynamic model RMA-2V used physical model-derived St. Mary's Inlet water levels and tributary velocity measurements for the boundary forcing conditions for an average tidal cycle. The numerical model was verified to physical model tidal elevations and depth-averaged velocity data for interior locations.

A wetting and drying algorithm was used to numerically model the extensive marsh and intertidal areas of the estuarine system. Marsh-estuarine circulation interaction and prescribed marsh elevation were found to be important in achieving proper hydrodynamic reproduction. Three separate numerical model schematizations or meshes of the Cumberland Sound system were verified as the submarine channel evolved in detail. RMA-2V demonstrated reasonable reproduction of pre-Trident and transitional channel hydrodynamic conditions for the Cumberland Sound/Kings Bay system.

Verification of the hydrodynamic and sediment transport hybrid modeling system for Cumberland Sound and Kings Bay navigation channel has been demonstrated. The developed modeling procedures can be used in carefully designed testing programs to assess potential hydrodynamic and sedimentation impacts associated with submarine plan channel and remedial measure alternatives.

Granat, Mitchell A. (1990). "Numerical Model Predictions of Cumberland Sound Sediment Redistribution Associated with Trident Channel Expansion," U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

A previously developed modeling system was used to identify potential areas of sedimentation impact or change associated with Trident channel expansion. The modeling system had been designed and verified to predict average currents and long-term average maintenance dredging requirements for the Kings Bay submarine channel. Excellent numerical model to field submarine channel sedimentation verification was previously demonstrated for the pre-Trident condition. The dramatic shoaling impact, a 150 percent increase in required yearly maintenance, predicted by the model for the tested Trident plan channel condition added to the interest in Cumberland Sound sediment redistribution.

Numerical model predictions of long-term average cohesive (clay and silt) and non-cohesive (sand and silt) sedimentation (erosion and deposition) patterns within Cumberland Sound are illustrated for pre-Trident and Trident channel conditions. Quantitative assessments should not be attempted for unverified areas; thus, only qualitative trend-type comparisons should be made for the unverified areas outside the channel area. In general, subtle sedimentation (erosion and deposition) pattern differences between the two conditions are illustrated. The presented results can be used to identify areas of potential impact for consideration in intensifying field monitoring or in modifying the Kings Bay Coastal and Estuarine Physical Monitoring and Evaluation Program.

Hall, Brad R., and Engel, John. (1995). "A Modeling Of Sedimentation Processes In A Bottomland Hardwood Wetland." *Proceedings, International Water Resources Engineering*

Conference, San Antonio, TX. American Society of Civil Engineers, New York, 1, 94-98.
For several years, the US Army Engineer Waterways Experiment Station has monitored several physical and biological parameters on the Rex Hancock Swamp on the Cache River for ecosystems modeling purposes. Measurements of suspended sediment grain size, concentration, and deposition quantities within the wetland system were obtained. Boundary conditions and overall sediment budget for the wetland were identified by sampling daily-suspended sediment loads at the upstream and downstream limits of the wetland system. The data obtained were then used to develop and test a TABS-MD numerical model of the wetland system.

Hauck, Larry M. (1992). "A Hydrodynamics At Mouth of Colorado River, Texas, Project; Numerical Model Investigation," Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
The Mouth of Colorado, Texas, Project includes a diversion channel of the Colorado River into the eastern arm of Matagorda Bay, a dam on the present Colorado River channel downstream of the diversion channel, a dam at Culver Cut, and a navigation bypass channel from the Gulf of Mexico to the city of Matagorda, TX. The project will create an intersection of the Gulf Intracoastal Waterway (GIWW) with the navigation bypass channel, which is the emphasis of this study. The freshwater flow diversion is expected to alter existing current patterns and tidal propagation in an area with navigational and recreational concerns.

The US Army Engineer District, Galveston, required that preliminary results from steady-state numerical simulations be produced initially and be followed by field investigations and long-term dynamic numerical simulations of hydrodynamics. Both the field data collection effort and the ship simulation study are described in separate reports.
This report describes the hydrodynamic steady-state preliminary results, verifications to prototype measurements, and long-term tidally influenced simulations using the vertically integrated two-dimensional numerical model, RMA-2V.

Hauck, Larry M., and Brown, Ben, Jr. (1990). "A Numerical Modeling Of Hydrodynamics, Brazos Island Harbor Project, Texas (Brownsville Ship Channel)," Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
The Brazos Island Harbor Project, south Texas, has been authorized for navigation channel improvements, which include deepening the Brownsville Ship Channel. A vertically integrated two-dimensional numerical model RMA- 2V is being used to simulate the Brownsville Ship Channel and the lower Laguna Madre. RMA-2V was used to produce the hydrodynamics (water levels and velocities) for existing and three alternative channel designs. These hydrodynamic conditions were used in a ship simulator study. Historical velocity (direction and speed) measurements taken at approximately hourly intervals during the period 15-18 July 1980 at several stations were used to verify RMA-2V. Water level measurements from 4 tide gages were available for the same period to facilitate model verification. Because the Laguna Madre exhibits large response to wind forcing, some of the inaccuracies in water level verification were suspected to be the result of the sparsity of wind speed and direction data in the prototype system for the model verification. The verified RMA-2V model was operated with a high amplitude diurnal (spring) tide with a temporally varying southeast wind at 4 to 20 mph. The wind was phased to increase both the ebb and flow velocities. With these tidal and wind conditions, RMA-2V simulated the hydrodynamics for existing and 3 alternative channel designs. The peak ebb and flood currents for each design were saved as

computer files for use in a separate ship simulator study.

Hauck, Larry M., Teeter, Allen M., Pankow, Walter, and Evans, Robert A., Jr. (1990). "A San Francisco Central Bay Suspended Sediment Movement; Report 1, Summer Condition Data Collection Program And Numerical Model Verification," Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
Field data were collected on currents, salinities, and suspended sediments intensively over a lunar day and sporadically over a fortnight in September 1988 for the purpose of identifying transport processes and conditions in central San Francisco Bay and for numerical model verification. Conditions were typical of a low freshwater inflow summer season in this area. A two-dimensional horizontal finite element model was applied and verified to field and physical hydraulic model data. The model is intended for future long-term studies of the fate of dredged material dispersed from the Alcatraz disposal site.

Heath, R. E., Teeter, A. M., Freeman, G. E., and Boyt, W. L. (1999). "Ashtabula River, Ohio, Sedimentation Study; Report 4, Numerical Model," U.S. Army Engineer Research and Development Center, Waterways Experiment Station, Vicksburg, MS.
The Ashtabula River flows north into Lake Erie at the city of Ashtabula in northeast Ohio. The Federal navigation project in the lower Ashtabula River contains a breakwater-protected harbor in Lake Erie and a navigable waterway extending about 3.2 km upstream to a point approximately 300 m downstream of the 24th Street Bridge. Sediments in the harbor and lower 600 m of the waterway are classified as suitable for open-lake disposal, whereas sediments upstream are classified as unsuitable for open-lake disposal. In the harbor and lower 600 m of the waterway, dredging operations are conducted as required to permit commercial navigation. Dredging operations in the remainder of the waterway were suspended in the 1970's, closing the channel to commercial navigation, in response to the increased cost of safe removal and disposal of sediments contaminated with heavy metals, chlorinated hydrocarbons, and polynuclear aromatic hydrocarbons. The waterway is heavily used for recreational navigation. Limited dredging operations were conducted in the reach upstream of the 5th Street Bridge in 1993 to maintain safe navigation conditions for recreational traffic.
Numerical hydraulic and sedimentation models of the lower Ashtabula River were developed using the TABS-MD modeling system. The objective of the model study described herein was to estimate the potential magnitude and spatial distribution of scour that may occur during extreme event, such as the 100-year return period flood, potentially causing exposure and dispersal of contaminants buried in the channel bed sediments. Other reports in the series describe field data collections and laboratory erosion experiments conducted in support of the model investigation.

Heath, R. E., Fagerburg, T. L., Parchure, T., Teeter, A. M., and Boyt, B. (2000). "Ashtabula River, Ohio, Sedimentation Study; Report 1, Field and Numerical Model Investigations of Channel Scour; 1994 Interim Results," U. S. Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory, Vicksburg, MS.
A field data collection effort was initiated on 4 June 1994 to monitor water-level fluctuations, suspended sediment concentrations, and bottom material sampling for sediment classification. Water level fluctuations, at 15-minute sampling intervals, were obtained at four locations using continuous recording water level sensors. Water samples, obtained during a significant water level rise, were collected using float activated automatic water samplers. Bottom

material samples were obtained using two types of sampling devices. A 6-inch box core sampler, for collecting undisturbed samples, and a push core sampler, for collecting samples for sub sectioning, were the devices used. River current measurements were performed at four data collection ranges. Acoustic Doppler Current Profile (ADCP) equipment were used to obtain the velocity data. Monthly service trips were scheduled to perform maintenance and data retrieval on the long-term equipment.
Preliminary data analysis of velocity profiles indicated the velocity range was 0-30 cm/sec. Laboratory erosion tests indicated the critical shear stress for commencement of surface erosion between 0.2-0.6 Pa.
A preliminary TABS-MD finite element modeling system was developed to provide multidimensional solutions to open-channel flow and sediment transport problems. Finite element meshes were developed using National Oceanic and Atmospheric Administration (NOAA) survey chart of the area and recent hydrographic survey data collected by the U.S. Army Engineer District, Detroit. Typical mesh element size was 120 m (400 ft) longitudinally and 18 m (60 ft) laterally.

Heath, Ronald E., and Copeland Ronald R. (1989). "An Application Of Two-Dimensional Model To Predict Fine Sediment Deposition." *Sediment Transport Modeling: Proceedings of the International Symposium,* New Orleans, LA, August 14-18, 1989. American Society of Civil Engineers, New York, 118-123.
The TABS-2 two-dimensional numerical modeling system was used to predict the potential for fine sediment deposition in the lock approach channels at Lock and Dam Nos. 4 and 5 on the Red River near Shreveport, Louisiana. This paper outlines the numerical modeling study procedure developed during the Red River navigation study with specific application at Lock and Dam Nos. 4 and 5. The paper describes the importance of hydrodynamic boundary conditions, sediment concentrations and sizes, and flow durations. The two-dimensional numerical model was very effective for evaluating specific design alteration and their effect on fine sediment deposition in the upstream and downstream lock approach channels.

Heltzel, S. B. (1985). The Impact Of The I-664 Bridge-Tunnel Crossing On Sedimentation. *Hydraulics and hydrology in the small computer age, proceedings of the Specialty Conference,* Lake Buena Vista, U.S.A., August 12-17, 1985. W. R. Waldrop, ed., American Society of Civil Engineers, New York, Session 4C, 1, 254-259.
The procedures used to study the effects of a proposed bridge tunnel crossing on sedimentation in the James River estuary, Virginia, U.S.A. are briefly described. A finite element hydrodynamic model, RMA-2V was used for a navigation channel study and a general sedimentation study. The non-cohesive or sand version of the finite element transport models of STUDH was used to investigate the navigation channels and evaluate shoaling changes. The cohesive or clay version was used to study the sedimentation. Details of the simulation studies are presented and no adverse impact of the proposed construction was indicated in the channels or in oyster ground areas.

Heltzel, Samuel B. (1988). "I-664 Bridge-Tunnel Study, Virginia; Sedimentation And Circulation Investigation, " Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
This report presents results from physical and numerical model tests on the effects of the proposed I-664 James River Bridge-Tunnel complex on (a) sedimentation in the federally maintained channels (Newport News, Norfolk Harbor, and Elizabeth River), (b) general

sedimentation in the lower James River, 8changes in overall flushing characteristics, and (d) changes in current velocities and flushing near the Craney Island disposal site.
The navigation channel sedimentation was evaluated using the TABS-2 finite element numerical models RMA-2V for hydrodynamics and STUDH for sedimentation with an existing numerical mesh of the Elizabeth River and lower James River areas. For the general sedimentation investigation, a new numerical mesh was created and the same numerical models, RMA-2V and STUDH, were used. Data for the flushing and currents evaluation were provided by the Virginia Institute of Marine Science.
Results from the physical model tests indicate circulation changes will be localized with minimal effects on the general circulation of the lower James River.
Results from the numerical sedimentation modeling indicate that sedimentation will be generally unchanged or reduced except on either side of the north island where increases can be expected. The areas experiencing unchanged or slightly reduced sedimentation rates include the oyster grounds, the Elizabeth River and Norfolk Harbor Channels, and the Newport News Channel.

Heltzel, Samuel B., and Granat, Mitchell A. (1988). "A Lower James River Circulation Study, Virginia; Evaluation Of Craney Island Enlargement Alternatives," Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
This report presents results from the numerical model investigation whose primary objective was to assess general changes in circulation, currents, and sedimentation associated with six proposed alternative expansion geometries of the Craney Island confined disposal facility. An additional objective of the study was to assess the effects of each of the six alternative geometries on the reported estuarine circulation cell (flow convergence) off Hampton Flats and Newport News Point.
This numerical model investigation used the TABS-2 finite element numerical models RMA-2V for hydrodynamics and STUDH for sedimentation with a modified version of an existing numerical mesh of the Lower James River. Other information presently available regarding the estuarine circulation and flow convergence observed off Newport News Point and Hampton Flats was reviewed.

Heltzel, Samuel B. (1992). "Evaluation Of Proposed Port Facilities, Charleston Harbor, South Carolina." *Proceedings of Ports '92,* Seattle, WA. American Society of Civil Engineers, New York, 791-801.
Often it is necessary for port facility designers to evaluate various alternative development plans for port facilities. These evaluations may include a ship navigability study or an evaluation of potential impacts to channel and facility shoaling and maintenance dredging requirements. A study of this type was performed for the South Carolina State Ports Authority (SCSPA) by the US Army Engineer Waterways Experiment Station. The study was designed to provide a preliminary evaluation of two alternative port facilities. This numerical model investigation used the US Army Corps of Engineers TABS-MD numerical modeling system for open channel flow and sedimentation. Boundary conditions and a verification data set were obtained from the laterally averaged numerical model Fine-Grained Bed Sediment (FIBS). The numerical model mesh used in this study is a comprehensive mesh of the Charleston Harbor system. Verification was very carefully conducted, and a sensitivity analysis was also performed on model parameters. This paper presents the results of this port facility evaluation.

Hewlett, J. Christopher, Daggett, Larry L., and Heltzel, Samuel B. (1987). "A Ship Navigation Simulator Study, Savannah Harbor Widening Project, Savannah, Georgia," Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

The US Army Engineer Waterways Experiment Station (WES) ship simulator was used to evaluate the proposed channel widening of the Savannah Harbor from Fig Island Turning Basin to Kings Island Turning Basin. The widening would extend the north side of the channel 100 ft. The present channel width of 400 ft causes difficulties in the maneuvering of the 950-ft New York Class container ships that began calling in Savannah approximately 2 years ago. For this reason, the simulation study was conducted using a numerical model of this container ship.

To generate channel currents for input into the simulation, a hydrodynamic finite element model of the Savannah Harbor was developed as part of the study. Boundary conditions for this model were obtained from a larger numerical model of the entire Savannah estuary system developed by the WES Hydraulics Laboratory Math Modeling Group. Prior to testing, professional pilots from Savannah conducted a series of runs for the purpose of validating the simulation.

The simulations consisted of existing and planned conditions. Inbound and outbound runs were performed in opposing currents from an extreme tidal range of 10.5 ft. A total of 42 runs were made, 10 outbound runs in the existing channel, 10 outbound runs in the planned channel, 11 inbound runs in the existing channel, and 11 inbound runs in the planned channel. Professional pilots from the Savannah Pilots Association conned the ship during the tests. Study results were based on a basic statistical analysis in which the means and standard deviations of the following maneuvering parameters in the existing and planned channels were compared: rudder angle, rate of turn, heading, revolutions per minute, speed, and clearances to the channel edge. Results of this analysis showed a small but consistent improvement in navigation in the planned channel.

Appendix A presents plots of the current model meshes for both the existing and planned channels. Appendix B shows plots of the current vectors from the finite element model. Appendix C shows all pilot track-lines plotted simultaneously for each test condition. Appendix D presents the pilots' ratings of the simulator and of the proposed channel widening and tabulates these comments.

Holland, J. P., Berger, R. C., and Schmidt, J.H. (1996). "Finite Element Analyses in Surface Water and Groundwater: an Overview of Investigations at the U.S. Army Engineer Waterways Experiment Station," *Third US-Japan Symposium on Finite Element Methods in Large-Scale Computational Fluid Dynamics,* March 31-April 3 1996, Minneapolis, MN.

No Abstract

Hunt, J., (2000). Ayres Associates, Fort Collins, CO.

Ayres Associates hydraulic engineers have applied RMA-2 and FESWMS to numerous studies throughout the country, including:

1. 20 miles of the Sacramento River floodplain in northern California (completed 1997).
2. The lower American River through Sacramento (ongoing).
3. The San Jacinto River in Texas (completed 1996).
4. The Choctawhatchee River in Florida (completed 1996).
5. The Altamaha River in Georgia (completed 1996).
6. The Turtle, Satilla, South Newport, and Medway Rivers in Georgia (completed 1999).

7. Biscayne Bay, Florida (completed 1998).
8. Boca Ciega Bay, Florida (completed 1999).
9. The south shore bay system of Long Island, New York (completed 2000).
10. The Kennebec River near Bath, Maine (1997).
11. The Cooper and Wando Rivers, South Carolina (2000).
12. The Ashley River, South Carolina (2000).
13. The Sacramento River at the Glenn-Colusa irrigation diversion (completed 1998).

Jones, Norman L., and Richards, David R. (1992). "A Mesh Generation For Estuarine Flow Modeling," *Journal of Waterway, Port, Coastal and Ocean Engineering,* American Society of Civil Engineers, 118(6), 599-614.
A finite element computer modeling system called TABS-2 has been developed by the U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. TABS-2 has been used to model shallow water flow in estuaries. Accurate modeling of the flow in estuaries using TABS-2 requires the use of very large two-dimensional finite element meshes. The task of constructing such meshes has traditionally been the most time-consuming and error-prone part of the modeling process. Most automatic mesh-generation schemes are not well suited for estuarine modeling because the regions modeled are typically highly complex and irregular. As a result, the meshes are often constructed manually by coding the mesh in an ASCII file. Manual construction of large meshes is very tedious and can take several weeks to complete. To overcome this difficulty, a mesh generation scheme well suited for estuarine modeling has been developed involving a triangulation algorithm and a variety of mesh editing tools. The scheme makes it possible to generate large meshes of several thousand elements in a relatively short period of time. In addition, the scheme results in meshes with favorable geometric properties, leading to stability and accurate solutions.

Krcma, K. V., (1999-2000). Ogden Beeman & Associates, Inc.
Ogden, Beeman & Associates, Inc. Application of RMA-2 or FESWMS include:
1. Columbia River, River Miles 63-66, OR & WA (1988)
2. Mouth of LA River, CA (1988)
3. McKenzie River, OR (1989)
4. Yamhill River, OR (1989)
5. Columbia River, River Miles 71-73, OR & WA (1989)
6. Mouth of Snohomish River, Everett WA (1990)
7. Mouth of the Pasig River, Manila, Phillipines (1992)
8. Columbia River, River Miles 127-130, OR & WA (1994)
9. Columbia River, River Miles 102-105.5, OR & WA (1998)
10. Willamette River near City of Corvallis, OR (1999)
11. Columbia River, River Miles 108-111, OR & WA (1999)

Letter, Joseph V., Jr. (1993). "A Grand and White Lakes Flood Control Project; Numerical Model Investigation," Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
The Grand and White Lakes flood control project provides protection over a broad portion of the Louisiana coastline. The study area involves a wide variety of wetlands and complex canals and waterways. The area supports many economic interests with potentially conflicting desires for management of the water resources. The project required the capability of quantitatively estimating the relative performance of a large number of design alternatives.

Numerical modeling techniques capable of addressing the flood routing and salinity intrusion processes required to evaluate project alternatives were developed. These techniques included the specification of control structures within the one-dimensional finite element formulation, utilization of marsh porosity, discretization of complex spatial geometric features of the wetlands, and the use of one-dimensional networking in conjunction with the two-dimensional finite element formulation.
Numerical testing was performed for eighteen separate design alternatives for the system. Flood events with 2-, 5-, 10-, 25- and 50-year return intervals were simulated and stage exceedance curves generated. Salinity intrusion testing was performed for the influence of marine organism ingress structures on the upstream basin.

Letter, J. V., Jr., Teeter, A. M., Pratt, T. C., Callegan, C. J., and Boyt, W. L., in draft, "San Francisco Bay Long Term Management Strategy (LTMS) for Dredging and Disposal, Hydrodynamic Modeling", Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
No Abstract

Letter, J.V., Jr., (1993). "Grand and White Lakes Flood Control Project: Numerical Model Investigation", Technical Report, US Army Engineer Waterways Experiment Station, Vicksburg, MS.
The Grand and White Lakes flood control project provides protection over a broad portion of the Louisiana coastline. The study area involves a wide variety of wetlands and complex canals and waterways. The area supports many economic interests with potentially conflicting desires for management of the water resources. The project required the capability of quantitatively estimating the relative performance of a large number of design alternatives. Numerical modeling techniques capable of addressing the flood routing and salinity intrusion processes required to evaluate project alternatives were developed. These techniques included the specification of control structures within the one-dimensional finite element formulation, utilization of marsh porosity, discretization of complex spatial geometric features of the wetlands, and the use of one-dimensional networking in conjunction with the two-dimensional finite element formulation
Numerical testing (RMA2 and RMA4) was preformed for eighteen separate design alternatives for the system. Flood events with 2-, 5-, 10-, 25- and 50-year return intervals were simulated and stage exceedance curves generated. Salinity intrusion testing was performed for the influence of marine organism ingress structure on the upstream basin. The results of the testing showed that the marine ingress structures should be very modest in size if salinity intrusion problems are to be avoided. The flood control testing suggested that the optimum location of the increased flow capacity should be near the mouth of the primary tributary, the Mermentau River, or else extensive channelization would have to accompany an alternate location.

Lin, Hsin-Chi J. (1992). "A Houston-Galveston Navigation Channels, Texas Project; Report 2, Two-Dimensional Numerical Modeling Of Hydrodynamics," Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
The Houston-Galveston Channel Project consists of about 65 miles of deep-water channels leading from the Gulf of Mexico to the Houston Turning Basin at the head of navigation and Galveston Channel, a side channel from Bolivar Roads to Galveston Harbor. The present channel dimensions are 400 ft wide and 40 ft deep at the mean low tide for most of the channel. The Galveston Channel is 1,125 ft wide and 40 ft deep at the mean low tide.

This study used the TABS-MD numerical modeling system to simulate water levels and currents of different channel design conditions for Houston-Galveston navigation channels. These hydrodynamic conditions were used in a separate ship simulator study.
Water level measurements at six tide gages and velocity measurements taken during a 14-hr survey on 18-20 July 1990 at five current stations were used to verify the model. A different subset of water levels from 20-22 November 1990 were used to further verify the model.
The verified model was used to simulate the hydrodynamics for the existing and two proposed channel configurations of the Houston Ship Channel and Galveston Channel. The peak ebb and flood currents and water levels for each design were used as computer files for use in the ship simulator study.
Comparisons of existing channel velocities with those for Phase I and Phase II of the project indicate slight increases in the lower part of Houston Ship Channel.

Lin, Hsin-Chi J., and Richards, David R. (1993). "A Numerical Model Investigation Of Saugus River And Tributaries, Massachusetts, Flood Damage Reduction," Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
The Saugus and Pines Rivers estuary is located along the Atlantic coast approximately 10 miles north of Boston, MA. Because of the topography and hydraulics of the Saugus and Pines river basins, a big storm event creates a significant flooding in the areas along the Saugus and Pines Rivers.
A plan was developed by the U.S. Army Engineer Division, New England, to provide flood damage reduction against the Standard Project Northeastern event. The principal component of this plan is construction of tidal floodgates at the mouth of the Saugus River.
The objectives of this study were to use the TABS-MD numerical modeling system to (a) provide upstream and downstream boundary conditions for testing the proposed floodgate plan in a physical model study; (b) determine the impacts caused by breaching of the I-95 embankment at the east branch of Pines River and widened Pines River openings in the I-95 embankment; and (c) evaluate the impacts of floodgate structure on basin tide levels, circulation patterns, and storm surges and sedimentation and the effect of sea level rise on these responses.
Since the proposed floodgate area has not experienced sediment problems, the sediment study was focused on a sensitivity analysis of model parameters. A 24-hr simulation was used to indicate any significant change in sediment deposition and scour pattern in the study area.
The RMA-2V model was successfully verified to limited field measurements including a 3-day field survey of water levels at nine tide gages and a 14-hr survey of velocity measurements at nine current stations. The comparisons of the computed water levels and velocities to field measurements were good.

Lin, H. C., Jones, N. L., and Richards, D. R. (1991). "A Microcomputer-Based System For Two-Dimensional Flow Modeling." *Proceedings of the 1991 National Conference on Hydraulic Engineering,* Nashville, TN, July 29-August 2, 1991. American Society of Civil Engineers, New York, 528-533.
An integrated, microcomputer-based system has been developed for simulation of two-dimensional, unsteady, free surface flows. The system consists of a finite-element mesh generation code, a 2-D hydrodynamic code, and graphical post-processors. The mesh generation code was specifically designed for interactive construction of irregular meshes and automatic generation of input files to the hydrodynamic code. The hydrodynamic code was adapted from RMA-2 in the TABS-2 system of models. Graphical displays of water surfaces

and velocities are presented. The microcomputer-based system provides engineers with a tool that can be applied to various studies of rivers, lakes, and estuaries. System usage and benchmarks for Macintosh and MS-DOS machines is provided. It provides economical and user-friendly desktop applications for most free surface flow problems.

Lin, H. J., Martin, W. D., and Richards, D. R. (1990). "A Dredging Alternatives Study, Cubits Gap, Lower Mississippi River;" Report 2, TABS-2 Numerical Model Investigation, Volumes I and II, Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
This report presents results from the numerical model investigation whose primary objective was to determine the best method to control shoaling in the navigation channel between Cubits Gap and Head of Passes. The secondary objective was to evaluate the best design configuration for a structural dike plan located at Cubits Gap and the ability of these designs to return the flow distribution to its historical levels.
Several plans were proposed by the US Army Engineer District, New Orleans, and local shipping interests to alleviate the recurrence of these shoaling conditions. They included a sediment trap, advance maintenance, and additional training structures. The first two addressed shoaling problems in the reach between Cubits Gap and Head of Passes. The latter addressed shoaling and flow distribution in Cubits Gap.
This investigation used the TABS-2 finite element numerical model RMA-2V for hydrodynamic analysis and STUDH for sediment transport computation. A large-flow 87-day hydrograph was used to determine the performance of each plan.

Lin, H. C., Jorgeson, J. D., Richards, D. R., and Martin, W. D. (1993). "A Comprehensive System For Surface Water And Groundwater Modeling." *Proceedings of the Federal Interagency Workshop on Hydrologic Modeling Demands for the 90's.* James S. Burton, compiler, Water-Resources Investigations Report 93-4018, U.S. Department of the Interior, U.S. Geological Survey, Reston, VA
The U.S. Army Engineer Waterways Experiment Station (WES) and Brigham Young University (BYU) have developed a computer interface system that greatly facilities the pre-processing, execution, and post-processing of watershed, surface water, and groundwater models. The actual computations are made with the models HEC-1 (hydrology), TABS-MD (surface water) and 3DFEMFT (groundwater). A common triangulated irregular network (TIN)-based data structure is used to ensure consistency between hydrology, surface water hydraulics, and groundwater flows. The interface allows easy construction of drainage basins and computes needed input parameters for hydrologic computations and display of hydrographs and flood boundaries. For surface water, the computational meshes and the boundary conditions are easily created and edited. Post-processing tools allow the display of velocity vectors and color-shaded contours of velocity magnitude and water surface elevations in additional to time histories at any point of interest. The groundwater module allows generation and editing of 3-D computational meshes and viewing of results through slices and color contours.

McAdory, R. T., Jr. (2000), Cape Fear-Northeast Cape Fear River, North Carolina; Numerical Model Study, U.S. Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory, Vicksburg, MS.
A three-dimensional hydrodynamic and salinity numerical model of the Cape Fear River Estuary, N.C., was developed, verified, and used in an experimental program. The purpose of the model was to determine salinity and water level changes in the estuary that may result

from a planned deepening of the Wilmington Harbor channel. The model included a discretized representation, or numerical grid, of the system, boundary condition forcings, and the RMA10-WES (TABS-MS) finite element code. Verification was realized by comparisons of model results to approximately eight weeks of prototype data for tides, velocities, and salinities. The experimental program consisted of calculating salinity and water level results for differing proposed channel depths and comparing these values to the base, or existing, conditions. The results indicate that deepening beyond 12.2 m (40 ft) resulted in average maximum tide height increases of 50 m (2 in) and small decreases in salinity in the Wilmington vicinity.

McAnally, W. H. (1987), Hybrid Modeling To Reduce Maintenance Dredging. *Third United States-The Netherlands Meeting on Dredging and Related Technology,* Charleston, SC, 10-14 September 1984. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
The hybrid modeling approach integrates physical modeling, numerical modeling, and analytical methods to produce results that are superior to other methods of predicting harbor sedimentation. The hybrid method has been described previously, but in brief, it applies each method to those processes for which it is best suited. For example, a physical model is used to describe three-dimensional hydrodynamics. Integrating the various solution methods permits the modeler to take advantage of the strengths of each method while avoiding its weaknesses. In this way, more processes can be modeled more accurately. This study indicates that the hybrid modeling approach, using TABS-2, provides an excellent tool for evaluation plans to reduce navigation channel maintenance.

McAnally, W. H., Jr. (1989). "Lessons From Ten Years Experience In 2D Sediment Modeling. *Sediment transport modeling;" proceedings of the International Symposium,* New Orleans, August 14-18, 1989. S. S. Y. Wang, ed., American Society of Civil Engineers, New York, 350-355.
Examines the work of the Hydraulics Laboratory, Estuaries Division, on two-dimensional models for sediment transport. Applications of the models include studies of navigation channel sedimentation rates, channel morphology changes, erosion/deposition characteristics of open water dredge spoil disposal and changes in suspended sediment concentration (dredging or model) and LAEMSED (width integrated vertical model).

McAnally, W.H. (1989). "STUDH: A Two-Dimensional Numerical Model For Sediment Transport." *Sediment Transport Modeling: Proceedings of the International Symposium,* New Orleans, LA, August 14-18, 1989. American Society of Civil Engineers, New York, 659-664.
TABS-2 water level and flow computations are performed by the generalized numerical model program RMA-2V; salinity and tracer transport computations are performed with RMA-4, and sediment transport computations are performed by STUDH. All three models use the finite element solution technique and can perform computations on the same computational mesh. STUDH performs only sediment transport computations, so hydrodynamics --water levels, current velocities, short period wave heights and periods -- must be computed externally and specified as input to STUDH. RMA-2V and STUDH use the same computational mesh and quadratic interpolation functions, so that the water level and velocity field generated by RMA-2V is exactly recreated by STUDH. STUDH calculates transport of sediment by solution of the unsteady, depth-integrated, 2D convection-diffusion equation with source/sink terms representing deposition/erosion processes and bed keeping routines that account for bed

structure (thickness, density, strength, etc.) Both cohesive and noncohesive transport are computed.

McAnally, William H., Jr., and Granat, Mitchell A. (1991). "A Cumberland Sound and Kings Bay, Pre-Trident and Basic Trident Channel Hydrodynamic and Sediment Transport Hybrid Modeling; Volume II: Appendix B," Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
A previously verified hybrid modeling system (coupled physical and numerical models) of the Kings Bay/Cumberland Sound estuarine system was used to investigate hydrodynamic and sedimentation variations associated with Trident channel expansion. Although not an explicit objective of the modeling efforts, tidal effects were examined. The tested plan condition was predicted by the models to result in higher high water and midtide level elevations in both physical and numerical models. Variations were close to, but greater than, model detection limits. Comparison of low-water elevations between the models was inconsistent.

This appendix specifically addresses the issue of tidal changes in a compact format. Pertinent information is compared with field observations and analytical considerations.

McAnally, W. H., and Stewart, J. P. (1982). "A Hybrid Modeling Of Estuarine Sedimentation." *Applying research to hydraulic practice, proceedings of the conference,* Jackson, MS, August 17-20, 1982. P. E. Smith, ed., American Society of Civil Engineers, New York, Session 8A, 408-417.
A hybrid modeling method using physical and numerical models in an integrated solution method was developed for use in solving estuarine sedimentation problems. The method was applied to the Columbia River estuary with a large physical model, finite element numerical models RMA-2V and STUDH, a finite difference wave propagation model and several analytical techniques.

McAnally, W H., Jr., and Thomas, W. A. (1980). "A Finite Element Models In A Hybrid Model Study Of Estuarine Sedimentation." *Finite elements in water resources; preprints of the Third International Conference,* Oxford, MS, May 19-23. University of Mississippi, University, MS.
This paper described how two finite element models fit into a hybrid solution method, and discussed experience gained in their application. Water surface elevation, current velocity, and salinity (in three dimensions) are measured briefly at a number of points in a physical model of the estuary. These measurements are used to drive a finite element numerical model for hydrodynamics-RMA-2. Output from RMA-2 and other models as required (e.g., a wind-wave propagation model) drives a two-dimensional finite element numerical model for sediment transport--STUDH. The several models are connected and complemented by a data management system and several pre- and post-processor computer codes. Present criteria for limits on element sizes, shapes, and time steps appear to be lacking. Rules of thumb and previous experience with what works and what does not are valuable guides, but practical, production-oriented model applications generally require that meshes be stretched to the limit in order to stay within time, cost, and computer resources. A related need is for continuing improvement in computational efficiency--a popular area of endeavor. Recent work made the finite element method competitive with other methods, but further improvements are a necessity.

McAnally, W. H., Berger, R. C, Teeter, A. M. (1993). "A Three-Dimensional Numerical Modeling For Transport Studies." *Proceedings, National Conference on Hydraulic Engineering,* San Francisco, CA. American Society of Civil Engineers, New York, 2, 2141-2146.
Modeling three-dimensional transport of salinity and sediments in estuarine flows requires that hydrodynamics be accurately modeled with sufficient precision to describe the advection and turbulent diffusion of salinity and sediments. These demands are considerably more stringent that those required for modeling water levels and discharges. Application of the model RMA10-WES and TABS-MD system of multi-dimensional models to San Francisco Bay salinity and sediment transport and Galveston Bay salinity illustrates the challenges involved. Residual flows in these bays reflect both density-driven flows, which are strongly three-dimensional, and tidal pumping, which are weakly three-dimensional, and tidal pumping, which is weakly three-dimensional. Asymmetry in bed stresses combined with these residual flows to induce three-dimensional sediment fluxes that may or may not be consistent with the residual flows.

McAnally, William H., Jr., Brogdon, Noble J., Jr., and Stewart, J. Phillip. (1983). "A Columbia River Estuary Hybrid Model Studies;" Report 4, Entrance Channel Tests, Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
A hybrid modeling approach using a fixed-bed physical model, numerical models, and analytical techniques was used to study navigation channel shoaling at the mouth of the Columbia River. Sixteen plans for reducing channel maintenance dredging at the existing 48-ft depth and at 55- and 60-ft depths were tested. Effects of the plans on tides and currents were found to be subtle. Nondeepening plans had minor effects on salinity intrusion while channel deepening increased salinities by 1 to 6 ppt up to about mile 18. Only one structural plan reduced shoaling below base conditions for the 48-ft channel.

McAnally, William H., Jr., Brogdon, Noble J., Jr., Letter, Joseph V., Jr., Stewart, J. Phillip, and Thomas, William A. (1983). "A Columbia River Estuary Hybrid Model Studies;" Report 1, Verification Of Hybrid Modeling Of The Columbia River Mouth, Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
The Columbia Hybrid Modeling System was applied to the mouth of the Columbia River estuary to evaluate alternatives for reducing navigation channel maintenance dredging. The hybrid modeling method using a physical hydraulic model, analytical techniques, and various numerical models in an integrated solution method that takes advantage of the strengths of each technique while avoiding its weaknesses. The methods accounted for the effect of tides, freshwater runoff, wind waves, and littoral currents on sediment transport, deposition, and erosion. The models were verified to satisfactorily reproduce observed prototype behavior.

McAnally, William H., Jr., Letter, Joseph V., Jr., Stewart, J. Phillip, Brogdon, N. James, Jr., Anthony, Thomas W. (1984). "A Columbia River Hybrid Modeling System," *Journal of Hydraulic Engineering* 110(3), 300-311.
A hybrid modeling method for predicting waterway sedimentation was developed and applied to the Columbia River Estuary. The method uses physical hydraulic models, two dimensional (2-D) numerical models, and analytical techniques in an integrated solution scheme. The hybrid modeling system used to study the Columbia consisted of a large physical model of the estuary, RMA-2V, a depth-integrated numerical model for sediment transport, and a collection of analytical methods. By using each model to address those phenomena that it is best able to

describe, an improved modeling technique is created.

McAnally, W. H., Letter, J. V., Stewart, J. P., Thomas, W. A., and Brogdon, N. J. (1984). "An Application Of Columbia Hybrid Modeling System," *Journal of Hydraulic Engineering,* American Society of Civil Engineers, 110(5), 627-642.
Describes application of the Columbia Hybrid Modeling System to navigation shoaling problems at the mouth of the Columbia River Estuary, U.S.A. A physical model was used for tidal elevations current speeds and directions at multiple depths and salinity concentrations. The numerical hydrodynamic model RMA-2V was used in conjunction with the physical model. Outlines specification of boundary conditions (slip flows, water surface elevations at nodes etc.). Describes time step and iteration procedures, wave analysis and computation of long shore (littoral) currents. Five events were used for verification of the model. Sedimentation modeling used the STUDH model. Examines some limitations of the methods used, notably two-dimensional treatment of sediment transport. Compares model and prototype dredged volumes, and shoaling pattern (scour and fill).

McAnally, William H., and Berger, R.C. (1997). "Salinity Changes in Pontchartrain Basin Estuary Resulting from Bonne Carre Freshwater Diversion", Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
Numerical model experiments were performed to predict salinity changes that will occur in the Lake Pontchartrain basin estuary, Louisiana and Mississippi, as a result of proposed Mississippi River freshwater diversions through the Bonnet Carre spillway near New Orleans. One purpose of the diversion is to reduce salinities in the Biloxi Marshes by 2 to 8 parts per thousand (ppt) in order to improve oyster productivity. A range of monthly salinities has been identified as the desired product of the project. Those salinities, called the Chatry salinities in this report, consist of a narrow band of "optimum" salinities and a somewhat wider band of "range limits."
A time-varying, three-dimensional numerical model of the estuary was constructed using the U.S. Army Corps of Engineers TABS-MD modeling system. The modeled area included Lakes Maurepas, Pontchartrain, and Borgne, Biloxi Marshes, and a portion of Chandeleur Sound plus connecting waterways of Mississippi River-Gulf Outlet (MRGO), Inner Harbor Navigation Canal, Gulf Intracoastal Waterway, Chef Menteur, and The Rigolets. All major tributary freshwater flows were simulated, as were tides at the Gulf of Mexico boundary and winds. The model computed instantaneous water levels and current velocities and salinities in three spatial dimensions throughout the area modeled. The model was verified to satisfactory reproduce hydrodynamic behavior observed in the natural system in 1982 and 1994.
Four conditions were modeled for April through August of a typical year: a Base condition with no diversion, Plan RT with freshwater diversions up to 20,000 cfs, Plan MBP5 with freshwater diversions up to 8,500 cfs, and Plan LBC1, with no freshwater diversions but with the connections between the MRGO and Lake Borgne closed.
The numerical model results were used to construct a simple regression equation that relates Biloxi Marsh salinities at a point to freshwater flows from the natural tributaries plus the diversions. The equation was then used to develop other diversion schedules that offered various salinity reduction scenarios.

McAnally, W. H., Berger, R. C., Teeter, A. M., and Letter, J. V., 1993. "Three Dimensional Numerical Modeling for Transport Studies," *Hydraulic Engineering '93; Proceedings of the 1993 Conference,* San Francisco, CA, July 25-30, 1993, Hsieh Wen Shen, S. T. Su, and Feng Wen, ed., American Society of Civil Engineering, New York, 6 pages.

MacArthur, Robert C., Pennaz, James, Freeman, Gary E., Weissinger, Lisa L., and King, Ian P. (1991). "A Enhanced Multi-Dimensional Modeling Of Marshes And Wetlands." *Proceedings of the 1991 National Conference on Irrigation and Drainage,* Honolulu, HI, July 22-26, 1991. American Society of Civil Engineers, New York, 794-800.
This paper summarizes the verification and application of a two-dimensional finite element model capable of simulating the complex circulation characteristics in marshes and wetlands for a variety of boundary and flow conditions. The new 'Marsh Elements and Culvert-Weir' version of computer program RMA-2V includes capabilities to simulate marsh hydrodynamics and culvert and weir flow along the margins of a marsh or wetland.

McCollum, Randy A., and Donnell, Barbara P. (1994). "A Claremont Terminal Channel, New York Harbor," Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
A ship simulator investigation of Claremont Terminal Channel was performed to determine the effects on ship handling of the proposed widening and deepening of the existing channel from approximately 150 ft to 300 ft and 27 ft mlw to 34 ft mlw, respectively. A hydrodynamic model study of the same area was conducted in support of the ship simulator investigation to supply current fields for the existing channel and proposed channel modifications. This report will describe the ship simulator investigation; it's conclusions, and recommendations. Appendix A will describe the hydrodynamic verification and numerical simulation of the existing Claremont Channel bathymetry and two proposed channel design plans. Appendix B describes the governing equations of the TABS-MD numerical modeling system.

Martin, William D., and Berger, R. C. (1989). "Southwest Pass Training Structure Alternatives." *Proceedings of the 1989 National Conference on Hydraulic Engineering,* New Orleans, LA, August 14-18, 1989. American Society of Civil Engineers, New York, 969-974.
The U.S. Army Engineer Waterways Experiment Station system of computer programs, TABS-2, was utilized to evaluate various structural plans for increasing channel velocities and sediment transport capacity in the lower Southwest Pass of the Mississippi River. The study area was limited to the lower 4 miles of the Pass. A high flow representing 900,000 cubic feet per second at Venice, Louisiana, was selected for analysis. A high-resolution finite element mesh that allowed detailed evaluation of velocity vectors was used to analyze seven alternative plans. This relatively quick and inexpensive analysis technique resulted in an optimal structural plan which provided maximum channel velocities at a minimal cost.

Melidor, Avenant, Thomas, W. A., and McAnally, W. H. (1984). "A Numerical Model Of Mississippi River at Lock and Dam 26." *Water for Resource Development, Proceedings of the Conference,* Coeur d'Alene, ID, August 14-17, 1984. American Society of Civil Engineers, New York, 64-66.
Replacement work was initiated in November 1979. The first stage cofferdam constricted about half of the river channel. As a result, the flow velocity at the construction increased causing considerable erosion, and the riverbed dropped about 20 ft during the period of May 1981 to May 1982. The St. Louis District had the Waterways Experiment Station (WES) conduct a physical, movable-bed, hydraulic model study of the scour problem. In addition, the district applied the TABS-2 Numerical Modeling System to the problem with assistance from WES Hydraulics Laboratory personnel. The results of the TABS-2 study are reported.

Miller, A. J., and Cluer, B. L. (1998). "Modeling Considerations For Simulation Of Flow In Bedrock Channels." In: Rivers Over Rock: Fluvial Processes In Bedrock Channels. Geophysical Monograph 107, Department of Earth Resources, Colorado State University, Ft. Collins, CO 80524
No Abstract

Nail, G. H., and Abraham, D. D., (2000). "Hydrodynamic and Sediment Transport Study of Sudbury River, Massachusetts," TR XX-XX, U. S. Army Engineering Research and Development Center, Coastal and Hydraulics Laboratory, Vicksburg, MS.
Numerical models were used to determine the transport potential for contaminated sediments in two reaches of the Sudbury River near Framingham, Massachusetts. These two reaches are comprised of two relatively small (narrow) reservoirs, one discharging into the other. They are essentially riverine in nature at flows characteristic of this study. A computational hydrodynamic model (RMA2) of the reaches was developed. Several known worst-case flood conditions were simulated and the model verified. A sediment transport model (SED2D) was then run using the hydrodynamic responses as the driving force to erode, transport and deposit sediments. The results of the simulation indicate a potential movement of contaminated sediments in the constricted and shallow areas of the reservoirs for the Standard Project Flood (SPF) conditions. For the lower flow test conditions, 3-year, 14 year, and 100 year flood frequencies, the numerical model computer simulations predicted movement of only negligible amounts of contaminated sediments. Only at the highest flow conditions (SPF) was the movement of sediment considered significant.

Norton, W. R., and King, I. P. 1977. "Operating Instructions for the Computer Program RMA2-2V", Resource Management Associates, Lafayette, CA.
No Abstract

Pankow, Virginia R. (1988). "A San Francisco Bay: Modeling System For Dredged Material Disposal And Hydraulic Transport," Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
A combination of physical and numerical models was used to simulate the hydrodynamic, circulation, and sediment transport characteristics of San Francisco and San Pablo bays. This simulation was done in response to a request by the US Army Engineer District, San Francisco, to develop a modeling tool that can define the fate of dredged material disposed at the Alcatraz disposal site.
Tide and current velocity data from the San Francisco Bay-Delta physical model were used to verify the vertically averaged hydrodynamic model, RMA-2V (Two-Dimensional Model for Free Surface Flows). This model was used to generate the velocity field for a dredged material disposal model, DIFID (Discharge From an Instantaneous Dump). The suspended sediment concentrations from DIFID and the geometry and hydrodynamic data from RMA-2V were used in the sediment transport model, STUDH (Sediment Transport in Unsteady Two-Dimensional Flows, Horizontal Plane), to establish sediment transport and dispersion patterns around the Alcatraz disposal site in central San Francisco Bay. Two model meshes were developed for this study: a comprehensive or global mesh of the entire system, and a more detailed inset mesh of the Alcatraz disposal area.

Parchure, T. M., Brown, B., and McAdory, R. T. (2000). "Design of Sediment Trap at Rollover

Pass, Texas," U. S. Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory, Vicksburg, MS.

Rollover Pass is a narrow manmade channel, which connects the Gulf of Mexico and Rollover Bay. The Gulf Intracoastal Water Way (GIWW) crosses the Rollover Bay on the north side of Rollover Pass. The U.S. Army Engineer District, Galveston, maintains a navigation channel, 38 m (125 ft) wide and 3.6 m (12 ft) deep within the GIWW for commercial barge traffic. Over the past several years considerable siltation has been taking place within the GIWW in the vicinity of the Rollover Pass area and periodic dredging is required for maintaining navigable depths. The objective of the study was to construct a working numerical model of the Rollover Pass area, and to use the model for design of a sediment trap, which will be feasible and effective in reducing the frequency of dredging in the GIWW.

The hydrodynamic model code RMA2, available at ERDC-CHL, was used to calculate the hydrodynamics of the system with a two-dimensional numerical model. The model was verified using field data. Velocity patterns under selected tidal conditions were generated. Computation and analysis of bed shear stress patterns were used along with the velocity data to estimate where and by how much sediment deposition is expected to occur. Several alternatives of sediment trap in terms of location, shape, size and depth were considered for evaluation. The factors taken into account in the design of the trap are described in the report. Three configurations out of these were examined with the model: (1) a sand trap proposed by the Galveston District, (2) a tentative layout of sand trap based on field data and (3) modified final layout based on the results of the tentative layout.

Parchure, T.M., Wilhelms, S.C., Sarruff, S., and McAnally, W.H. (2000). "Salinity Intrusion in the Panama Canal," U.S. Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory, Vicksburg, MS.

The Panama Canal connects the Atlantic and Pacific Oceans for purposes of navigation. On its Way it crosses Miraflores Lake and Gatun Lake. Three navigation locks at each end of the Canal lift ships from the ocean to Gatun Lake through a height of 26 m (85 feet) above sea level and then lower them through three locks, bringing them back to the ocean level. Fresh water from Gatun Lake used for filling the locks is eventually lost to the sea while transferring ships from the lake to the sea. The net loss of fresh water is about 52 million gallons per lockage operation. Salt water from the ocean gets added to the lake during transit of ships from the ocean to the lake. Currently about 38 ships transit the Canal daily. The Panama Canal Commission (PCC) is considering engineering options for increasing the number of vessels transiting each day. It is feared that increased saltwater intrusion may occur and the Gatun Lake water may also become unsuitable for drinking. The Coastal and Hydraulics Laboratory of the U.S. Army Engineer Research and Development Center (ERDC), Waterways Experiment Station (WES), Vicksburg made preliminary computations for the extent of salt intrusion and a feasibility-level evaluation of mitigation measures.

The work consisted of the following: (a) Examination of field data, (b) Review of literature on prevention of salt water intrusion in navigation locks, (c) Mass balance model for Miraflores and Gatun lakes, (d) Evaluation of salinity intrusion and freshwater consumption mitigation alternatives. The following numerical tools were developed: (a) A simple mixing analysis coded in spreadsheet form that provides zero-dimensional models for the salinity of individual locks and the two lakes plus a freshwater consumption model for Gatun Lake, (b) A depth-integrated two-dimensional numerical model TABS-MD for dispersive transport of salt water into Gatun Lake, (c) A width-integrated two-dimensional numerical model for densimetric advection and dispersion of salty water from the locks into a channel. The zero-

dimensional models have been adjusted to yield results roughly comparable to a limited field observation of salinity in the Panama Canal. The two-dimensional models are physics-based and have been successfully applied in many applications; however, they have not yet been verified to field observations in Gatun Lake.
A feasibility-based evaluation of the following alternatives was conducted: (a) Use of holding ponds to conserve fresh water by recirculating lift water, (b) Installation of a Syncrolift lock chamber adjacent to the Miraflores and Gatun Locks, (c) A sump in the channel upstream of the locks to capture more dense salty water and drain it from the lake, (d) A grated chamber upstream of the locks to hold salty water while it is drained to the sea and replaced with freshwater.

Pokrefke, T. J., Jr., Nickles, C. R., Raphelt, N. K., Trawle, M. J., and Boyd, M. B. (1995). "A Redeye Crossing Reach, Lower Mississippi River;" Report 1, Sediment investigation, Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
The sedimentation study conducted on the Redeye Crossing Reach of the Mississippi River about 3 miles downstream of Baton Rouge, LA, was a combination of numerical and physical movable-bed model studies to aid in the development of a satisfactory dike design for this reach. A two-dimensional numerical model, TABS-2, was used to predict the reduction in dredging that could be anticipated with the original dike design and subsequent modifications. Those modifications included changing the length, height, location, and number of spur dikes. The plans investigated addressed the required dike plan to maintain the existing 40-ft navigation channel through the reach and an enhancement of that plan to provide a 45-ft channel to be developed in the near future.
Since no dikes presently exist in this portion of the Mississippi River, the physical movable-bed model study was also conducted to take advantage of the capabilities of both types of models. Thus the overall study allowed use of the numerical model to screen plans and the physical model to address detailed impacts of the plans. The physical model was constructed to a horizontal scale of 1:240 and a vertical scale of 1:200 including the river channel and over bank areas to the adjacent levees. During the overall testing program the numerical model was used to refine and test dikes plans. The dike plans deemed most successful from the numerical sedimentation model were also tested on the physical model.

Raphelt, Nolan K., Trawle, Michael J., Weissinger, Lisa L. (1991). "A River Dike Design Using A Numerical Model Approach." *Proceedings of the 1991 National Conference on Hydraulic Engineering,* Nashville, TN, July 29-August 2, 1991. American Society of Civil Engineers, New York, 435-440.
The preliminary design of a dike field at Redeye Crossing on the Mississippi River (Baton Rouge, Louisiana) is discussed. The TABS-2 modeling system was used to develop a two dimensional sediment transport model of the Mississippi River from River Mile 228 downstream to 206. Numerical model results are presented. The numerical modeling effort included dynamic simulations two years long to evaluate the impact of proposed dike field layouts on dredging requirements. An assessment of the model's applicability to the design of dike fields consisting of submerged rock dikes and model limitations encountered during the study are presented.

Richards, D. R. (1988). "A New Haven Harbor Numerical Model Study," Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
This report presents the results from a numerical model study of the impacts of deepening and

widening the approach channels and inner turning basin in New Haven Harbor, CT. Results from the study were intended to determine changes in circulation, which might affect valuable oyster resources, and to form the current fields needed to provide a detailed ship simulation study of the navigation improvement project. The US Army Corps of Engineers numerical modeling system, TABS-2, was used to predict the changes that might occur to circulation patterns in New Haven Harbor and portions of Long Island Sound. Currents were predicted in the navigation channel as well as in distant shallow regions where there is a significant shellfish fishery.

Richards, D. R. (1990). "A Flow Separation Around A Solitary Dike; Eddy Viscosity And Mesh Considerations." *Hydraulic Engineering: Proceedings of the 1990 National Conference,* San Diego, CA, July 30-31, 1990. American Society of Civil Engineers, Boston Society of Civil Engineers Section, Boston, MA, 2, 867-872.
The hydrodynamic model RMA-2V has been verified on a variety of global circulation studies. These studies rarely involved separated flow patterns around sudden expansions or contractions. This paper presents results from numerical and physical studies of separated flow around a solitary dike. Particular emphasis is placed on eddy viscosity and mesh refinement issues as they pertain to numerical model accuracy.

Richards, David R., Athow, Robert F., and Anderson, Jerry L. (1987). "A Numerical Modeling Of Estuarine Training Structure Effects On Navigation Channel Performance." *Coastal Zone '87: Proceedings of the Fifth Symposium on Coastal and Ocean Management,* Seattle, WA, May 26-29, 1987. American Society of Civil Engineers, New York, 1575-1587.
A two-dimensional, vertically averaged, numerical modeling technique is presented to analyze estuarine training structure performance. The technique consists of using the U.S. Army Corps of Engineers TABS-2 numerical modeling system with special emphasis on high-resolution grids and rigorous model verification procedures. Physical model experimental results are compared with the results obtained from the numerical model simulation for purposes of model verification.
A typical estuarine reach of the Columbia River is simulated in the numerical model, modeling both impermeable and permeable dike fields. Excellent numerical simulation of the expected velocity fields was achieved. It is concluded that some secondary currents can be successfully simulated using the required resolution.

Sanchez, J. A., and Evans, R. A., Jr. (2000). "Lower St. Johns River and Estuary, Florida, Numerical Model Study," U. S. Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory, Vicksburg, MS.
The U. S. Army Engineer Research and Development Center (ERDC) developed a multidimensional hydrodynamic and salinity model of the Lower St. Johns River and Estuary (LSJRE) Florida. The developed model was intended as a general planning tool to gain insight into the hydrodynamics and transport mechanisms of the system. Model results were verified against prototype hydrodynamic and salinity data. The model satisfactorily reproduces tidal elevation, discharges, and salinity trends.

Sanchez, Jose A., and Roig, Lisa C. (1997). "A Hydrodynamic and Sediment Transport, Mill Cove, St. Johns River, Florida, Numerical Modeling Study," Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
The U.S. Army Engineer District, Jacksonville, is investigating how to improve tidal flushing

in Mill Cove, lower St. Johns River, Florida, to maintain water quality and to prevent excessive sedimentation. Four plans have been proposed to reshape the shoreline within the cove. One additional proposed plan would also modify the bathymetry in the area. RMA2-WES, a two-dimensional, vertically averaged hydrodynamic model, was used to compare the circulation patterns that occur in the present-day Mill Cove against the circulation patterns that would result from the five plan configurations. Sediment transport was simulated using SED2D-WES, a two-dimensional, vertically averaged model of sediment advection and dispersion in the water column, with the channel bed acting as a source and/or sink for sediment as it deposits and erodes. Currents and tides were compared to prototype data to validate the
numerical model. The study addressed changes within Mill Cove as well as any influence these changes had in the navigation channel.

Smith, Tamsen M., McAnally, William H., Jr., and Teeter, Allen M. (1987). "A Corpus Christi Inner Harbor Shoaling Investigation," Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
A combination of numerical models was used to test alternatives for shoaling prevention in Corpus Christi Harbor, Texas. The vertically averaged model system, TABS-2, was used to simulate contributions of sediments by bay waters to the sediment load. The laterally averaged estuarine model, LAEMSED, was used to simulate density currents in the channel and sedimentation that occurs at the harbor entrance.
Applications of the models testing advance maintenance, removal of industrial discharges and withdrawals, advance maintenance in conjunction with a sill, and movement of the disposal areas showed a 20 percent decrease in shoaling as a result of industrial activity removal, a 75 percent decrease in sediments entering the bay channel due to disposal area relocation, and practically no effect on shoaling rates resulting from advance maintenance.
Appendix A presents the results of a reconnaissance survey on shoaling conditions in Corpus Christi Harbor. Appendix B describes the TABS-2 numerical modeling system, and Appendix C describes the theoretical aspects of LAEMSED.

Soong, Ta Wei, and Bhowmik, Nani G. (1991). "A Two-Dimensional Hydrodynamic Modeling Of A Reach Of The Mississippi River In Pool 19." *Proceedings of the 1991 National Conference on Hydraulic Engineering,* Nashville, TN, July 29-August 2, 1991. American Society of Civil Engineers, New York, 900-905.
A depth-integrated finite-element model (RMA-2V) was applied on a section of the Upper Mississippi River to study the hydraulic characteristics of the flood plain-river system. The area that has been modeled is called 'Montrose Flats.' Aquatic vegetation is abundant at this location, and the flow structure needs to be evaluated in order to study the nutrient transport conditions within this area. The present study focused on a large oval eddy that was observed to form in this area near the downstream end of the Devil's Creek delta. Causative factors for this eddy were examined by using this numerical model.

Stockstill, R. L., Martin, S. K., and Berger, R. C. (1995) "Hydrodynamic Model Of Vessel- Generated Currents," Regulated Rivers: Research & Management, Vol 11, 211-225, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
The draw down and return currents of vessels navigating in channels have previously been described by empirical relations or by using physical models. The empirical solutions are generally limited in scope to idealized channel shapes. Physical models are unrestricted in this

respect, but have limitations related to expense and scale effects. In this paper, vessel effects are modeled numerically. The vessel's displacement is represented by a moving pressure field. The movement of the pressure field is spatially varied in time, representing a vessel navigating along a channel. The hydrodynamics are described using the two-dimensional shallow water equations, which are modified to account for the effects of the imposed pressure field. A Petrov-Galerkin finite-element scheme using characteristic-based weighting is used to solve the governing equations. This Petrov-Galerkin test function is specifically designed to model flow
fields containing large gradients such as those found in the vicinity of the moving vessel. The numerical results for return flows and water surface elevations are compared with flume results of vessel passages.

Stockstill, Richard L., Berger, R. C., and Nece, Ronald E. (1997). "Two-Dimensional Flow Model For Trapezoidal High-Velocity Channels," *Journal of Hydraulic Engineering*, American Society of Civil Engineers, ISSN 0733-9429/97/0010-0844-0852.
A two-dimensional numerical flow model for trapezoidal high-velocity channels is developed. The model is designed specifically for simulation of flow in channels having sloping sidewalls in which the depth is an unknown variable in the governing equations and therefore the plan view of the flow domain is not known a priori. Solutions are obtained by time stepping from specified initial conditions using an implicit Petrov-Galerkin moving finite-element representation of the governing equations. The moving finite-element model produces a simultaneous solution for the boundary displacement and flow variables. This implementation provides stable solutions for supercritical flow even at relatively large Courant numbers. The model is tested by comparison of simulation results with laboratory data. These data sets serve as a basis for evaluation of the numerical model and should also prove useful to researches in testing other numerical flow models applied to supercritical flow in channels having sloping sidewalls.

Stockstill, R. L. (1997). "Implicit Moving Finite Element Model of the 2D Shallow-Water Equations," *Moving Boundaries IV, Computational Modeling of Free and Moving Boundary Problems,* ed. R.V. Keer and C. A. Brenbbia, Computational Mechanics Publications.
This paper describes a method for determining implicitly, the waterline and flow variables in shallow water. In particular, the shallow-water equations are applied to open channels with sloping sidewalls and dam-break flow over initially dry beds. The domain limits are time dependent in both cases, but only the former has a steady state. Arbitrary Lagrangian-Eulerian descriptions of the two-dimensional shallow-water equations are used to describe the time-dependent waterline formed by the water-surface/channel-bed intersection. The model uses and implicit Petrov-Galerkin moving-finite-element representation of the shallow-water equations. Simultaneous solutions of the two-dimensional shallow-water equations and waterlines are obtained. The implicit approach relaxes time-step size limitations and the Petrov-Galerkin test function provides numerical stability for advection-dominated flows. The model offers a viable means of representing shallow-water flows where the boundary locations are not known *a priori.*

Stockstill, Richard L. (1995). "2D Modeling of Class B Bridge Flow in Steep Channels," *Proceedings of the First International Conference on Water Resources Engineering,* American Society of Civil Engineers.
Bridge piers located in flood control channels are classified by the relation of flow depth

through the bridge section to critical depth upstream, between, and downstream of the piers. The term Class B flow is applied to conditions in which sub critical flow approaches the bridge, passes through critical depth at a point along the piers, and then jumps to sub critical flow or remains supercritical depending on the downstream conditions. The far field dlow upstream of the bridge may be sub critical or supercritical. The flow studied in this paper are of the Class B type in hydraulically steep channels. The bridge pier constriction chokes the flow producing a hydraulic jump upstream of the piers. The flow downstream of the piers is supercritical. The numerical flow model HIVEL2D is used to simulate the rapidly varied flow. HIVEL2D is a depth-averaged, two-dimensional (2D) flow model designed specifically for flow fields that contain supercritical and sub critical regimes as well as the transitions between the regimes. Simulation results are compared with published laboratory data.

Stockstill, Richard L. (1994). "Application of a Two-Dimensional Model of Hydrodynamics to San Timoteo Creek Flood-Control Channel, California," Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

The San Timoteo Creek, located in southern California, is a tributary of the Santa Ana River and drains portions of the San Bernardino and Riverside Counties. The existing creek has the capacity to protect the surrounding community from approximately a 20-year-frequency flood. The proposed channel improvements will provide a 100-year level of protection. The proposed channel design within the reach studied includes a sediment basin, a concrete weir followed by a converging sidewall chute, a compound horizontal curve, and a bridge pier. This study was initiated because there was concern as to the adequacy of a one-dimensional analysis of the flow conditions within the channel chute. A two-dimensional analysis was deemed necessary to evaluate the chute's influence on the flow conditions in the curve and the curve's impact on the flow conditions at the bridge

The two-dimensional, depth-averaged flow model, HIVEL2D, was used to simulate the flows in the high-velocity channel. This model was chosen because of its ability to simulate supercritical flow and capture shocks such as oblique standing waves. Simulation results indicated that the proposed San Timoteo Channel design and in particular, the San Timoteo Canyon Road bridge, will convey the design discharge (100-year frequency event, 19,000 cfs) in an acceptable manner.

Stockstill, Richard L. (1996). "A Two-Dimensional Free-Surface Flow Model for Trapezoidal High-Velocity Channels," Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

A two-dimensional free-surface numerical flow model for trapezoidal high-velocity channels is developed. The model addresses common hydraulic features of high-velocity channels including sub critical or supercritical flow, which may undergo transition from one regime to the other and can be further complicated by the presence of oblique standing waves. The model is designed specifically for simulation of flow in trapezoidal high-velocity channels in which the depth is an unknown variable in the governing equations; therefore, the plan view of the flow domain as delineated by the water surface/bank interface is not known a priori. Steady state solutions are obtained by time stepping from specified initial conditions using an implicit Petrov-Galerkin moving finite element representation of the governing equations. As the computed flow field evolves from the specified initial flow conditions and initial boundary location to the steady state, the moving finite element model adjusts the location of side boundaries with the depth solution. The algorithm includes a novel method for solving the boundary displacement and the flow variables simultaneously.

Testing of the computational model consists of comparing model results with analytical solutions and laboratory flume data. These tests demonstrate that the numerical model can be used as a tool for the evaluation of trapezoidal high-velocity channel designs.

Stockstill, R. L. (1994). "HIVEL2D: "A Two-Dimensional Flow Model for High-Velocity Channels," Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
A numerical flow model, HIVEL2D, has been developed as a tool to evaluate high-velocity channels. HIVEL2D is a depth-averaged, two-dimensional flow model designed specifically for flow fields that contain supercritical and sub critical regimes as well as the transitions between the regimes. The model is a finite element description of the two-dimensional shallow-water equations in conservative form. Provided in this report are a description of the numerical flow model and illustrative examples of typical high-velocity flow fields that the model is capable of simulating. Model verification is obtained by comparison of simulation results with data obtained from flume studies. Model assumptions and limitations are also discussed.

Stockstill, R. L., Berger, R.C. (1999). "A Two-Dimensional Flow Model for Vessel-Generated Currents", ENV Report 10, US Army Engineer Waterways Experiment Station, Vicksburg, MS.
The movement of a barge train through a body of water produces a complex pattern of currents and waves. Quantification of these currents has relied on physical models and analytical descriptions. Although empirical methods are practical for many situations, detailed analyses of specific areas are desirable. These empirical relations do not provide time-varying solutions necessary for predicting the duration of vessel-induced events. Also, spatial variations in rivers having backwaters and side channels are not modeled by these expressions. A two-dimensional representation of the equations of motion provides temporal variation of the depth-averaged velocity distribution and the water-surface elevation. This report describes the development of a numerical model (HIVEL2D) to quantify vessel-generated currents and summarizes a series of numerical experiments. Flow fields containing a moving vessel are modeled by specifying a pressure field, representing a vessel hull that is spatially varying in time. The movement of the pressure field in time is specified to represent a vessel navigating along a channel.

Teeter, Allen M, Letter, Joseph V. Jr., Pratt, Thad C., Callegan, Christopher J., and Boyt, William L. (1996). "A San Francisco Bay Long-Term Management Strategy (LTMS) For Dredging and Disposal," Report 2, Bay wide Suspended Sediment Transport Modeling, Technical Report , U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
Field data analysis was used to examine suspended sediment transport in Central San Francisco Bay, and to develop and verify a two-dimensional numerical fine-grained sediment transport model. This study concerned the dispersion and fate of disposed dredged material in Central San Francisco Bay, California. The 1992 monitoring survey spanned a 2-week period in June, and used three boat-mounted acoustic Doppler current profiling (ADCP) systems to obtain repeated cross-sectional transects near the Golden Gate, the entrance to South Bay, and Richmond Point. Between acoustic transects, water samples were obtained over depth for salinity, total suspended material (TSM) concentration, and particle size determinations. Acoustic backscatter data were used to produce correlated suspended material concentration and flux fields. Discrete measurements were fit to empirical discharge and suspended flux

models and integrated over a neap-spring-neap-tidal sequence to estimate net transport.

Teeter, Allen M., and Pankow, Walter (1989). "Schematic Numerical Modeling of Harbor Deepening Effects on Sedimentation, Charleston, South Carolina," U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
This report describes schematic numerical model analysis of harbor channel deepening effects on sedimentation for Charleston Harbor, Charleston, SC. The harbor channel is being deepened from –35 to –40 ft mean low water, and the harbor freshwater inflow has been recently decreased from about 15,600 to 4,500 cfs average. Existing hydraulic and sediment information was used.
The schematic numerical modeling approach was selected because no simpler (analytical or steady state) shoaling prediction was known which could account for both channel deepening and altered inflow conditions. A two-dimensional laterally averaged numerical model Fine-Grained Bed Sediment (FIBS) with 1- and 2-mile node spacing was used.

Teeter, A. M., Brown, G. L., Callegan, C J., McVan, D. C., and Sarruff, M. S., (2000). "Sedimentation Response to Wharf Expansion Plans for the Columbus Street Terminal, Charleston, South Carolina," U.S. Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory, Vicksburg, MS.
Field information on currents, suspended sediment concentrations, and bed material properties was collected in the vicinity of the Columbus Street Terminal, Town Creek Lower Reach, Charleston Harbor, S.C. An existing three-dimensional finite-element numerical hydrodynamic and sediment transport model was modified to provide greater spatial resolution in the study area, checked against field data, and operated to predict the sedimentation response which would result from the offshore expansion of the terminal wharf. Bed sediment near the wharf were clayey, sandy silts with densities of about 1,200 wet-kg/m^3. Sediment grain size and bulk wet density generally increased with distance off the wharf and upstream. Acoustic Doppler current profiles indicated that near-bottom currents converged toward the wharf, especially on flood-tidal phase.
Appreciable vertical gradients were observed in suspended sediment concentration fields. The proposed expansion plans would move the wharf face closer to the channel centerline. The TABS-MD numerical model predicted a modest improvement in the sedimentation along and 46 m out from the wharf face.

Thomas, William A., and Heath, Ronald E. (1984). "Application of TABS-2 To Greenville Reach, Mississippi River." *River meandering, proceedings of the conference Rivers '83,* New Orleans, LA, October 24-26, 1983. American Society of Civil Engineers, New York, 908-919.
No Abstract

Thomas, W. A., Heath, R. E., Stewart, J. P., and Clark, D. G. (1988). "The Atchafalaya River Delta;" Report 5, the Atchafalaya River Delta Quasi-Two-Dimensional model of delta growth and impacts on river stages, Technical Report HL-82-15, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
A quasi-two-dimensional sediment movement computer program was verified to historical bed deposition and scour and used to forecast delta growth for the next 50 years. The results are compared with growth rates predicted by several other methods in Report 6 of this series, "Interim Summary Report of Growth Prediction."

Webb, Dennis W., and Daggett, Larry L. (1991). "A Ship Navigation Simulation Study Brazos Island Harbor 42-Foot Improvement Brownsville, Texas," Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
A real-time ship simulation investigation of the proposed design for deepening and widening the man-made Brazos Island Harbor Channel, Brownsville, TX was conducted. The purpose of this study was to determine if the navigation channel could be deepened from 36 to 42 ft without widening the existing channel width of 200 ft or if the channel required widening to 250 or 300 ft as authorized. A numerical model of the existing ship channel from the Gulf of Mexico to the turning basin at the Port of Brownsville was developed. This model was verified by a member of the Brazos-Santiago Pilots Association. Numerical models of three plans were also developed, one with the existing channel deepened to 42 ft, one with the channel widened to 250 ft and deepened to 42 ft, and the other with the channel widened to 300 ft and deepened to 42 ft. The 250-ft-wide channel had a 100-ft-wide and 15-ft deep side channel for tow traffic. Tests were run in Brownsville on the US Army Engineer Waterways Experiment Station portable ship simulator.
These tests demonstrated that 250 ft is the optimum width for the Brazos Island Harbor Channel at a depth of 42 ft.

Zhang, H., PhD (2000). "Two-Dimensional Hydrodynamic Modeling of Dongting Lake", AGRA Earth & Environmental LTD, Calgary, Alberta.
No Abstract